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ABSTRACT

This pilot study was concerned with developing instructional materials for a single conceptual scheme that pervades all of science -- the principle of energy conservation. Some of the objectives of the project were to (1) determine whether a sequence of learning activities could be developed which would enable elementary school children to obtain an understanding of the conceptual scheme (2) to determine whether these activities would produce a progressively sophisticated understanding of the subordinate concepts considered to be components of that scheme (3) to identify the kinds of resources needed to develop a conceptually oriented elementary science program (4) to evaluate the efficacy of procedures used in the various steps of the program and (5) to identify problems that are encountered by elementary school teachers who attempt to use such a conceptually oriented program in science, particularly as these problems have implications for teacher training programs. Each of these objectives and the steps taken to achieve them are discussed in detail in the report. The last two sections discuss the findings of the study, with recommendations for further use of the materials and for further curriculum development along these lines. (BC)

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A PILOT PROJECT TO DEVELOP AN ELEMENTARY SCIENCE SEQUENCE

Project No. H281
Contract No. OE-6-10-175

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August 1967

New York University
New York, New York

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INTRODUCTION

This report concludes the COPES pilot study, a two-year project designed to test the feasibility of a K-6 science curriculum centered on the major conceptual schemes in science.

The rationale for such an approach to elementary science is the conviction that it affords both children and teachers a better grasp of the essentials of science than does the usual curriculum.[1] If we want students to attain a level of understanding and appreciation of the scientific enterprise that will serve them through their adult lives, it seems reasonable to begin by focusing their attention on the "great ideas" in science--the broad, inclusive conceptual schemes in terms of which we seek to account for the familiar facts of nature. These ideas represent the pinnacle of explanation in science and most clearly portray its intellectual and creative aspects.

Our motivation for seeking to develop a new and different curriculum was the realization that general education in science has pretty much missed its goal of a scientifically literate adult public. The educated adult population holds the most naive views of the natural world and of the scientific enterprise itself. Science clearly belongs with those disciplines that traditionally have been regarded as essential to man's cultural enrichment; yet the average person evidently fails to see it in this light. It was primarily in an attempt to alter this situation--to pave the way toward greater scientific literacy among the general public--that the present program was initiated.

We believe that such a conceptually oriented approach may have genuine survival value, that long after he has forgotten the facts of science, a student exposed to such a curriculum may at least retain an overall view of science that has not been distorted by undue emphasis on natural history and technology. The use of conceptual schemes or "big ideas" in science education is not new, of course; there have been numerous advocates in the past who have stressed these ideas in science education. But judging by the science curricula and textbooks that have appeared during the last few decades, it appears that for the most part these ideas have been submerged in detail. We conclude that it may be just this lack of focus which leaves so many students without a solid framework in science and causes them to regard it as little more than a vast collection of isolated facts.

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[1] Morris H. Shamos, "The Role of Major Conceptual Schemes in Science Education," The Science Teacher, 33: 27-30, January, 1966; National Science Teachers Association, Theory into Action in Science Curriculum Development (Washington, D.C.: The National Science Teachers Association, 1201 16th Street, N.W., Washington, D.C. 20036, 1964).

It has long been apparent, well before the COPES program was initiated, that much more could be accomplished with science in the elementary grades than had been thought possible in the past. Our experience lends a great deal of support to this view; the motivation toward science and the ability of children at this level to deal with scientific concepts do appear to have been grossly underestimated. One of our basic assumptions was that in these formative years, when minds are so receptive to new ideas and modes of thought, it should be possible to develop a foundation in science that will remain a permanent part of the individual's intellectual life.

The pilot study dealt with a single conceptual scheme that pervades all of science--the principle of energy conservation. This scheme was selected, not only because it cuts across all the science disciplines, but also because it seemed to afford a particularly challenging test of the effectiveness of a conceptual approach to elementary science. It is a conceptual idea not easily grasped by students and not readily susceptible to direct experimental verification. Yet it is one of the cornerstones of modern science, with which we believe every educated person ought to be familiar.

The pilot study was undertaken to accomplish the following objectives:

(1) To determine whether a sequence of learning activities that is scientifically sound and psychologically plausible can be developed which will enable elementary school children to obtain an understanding of a selected conceptual scheme.

(2) To determine whether the learning activities that are developed for teaching a given conceptual scheme produce a progressively sophisticated understanding of the subordinate concepts that are considered to be components of that scheme.

(3) To determine the kinds of resources that are needed to develop such a conceptually oriented program in elementary science.

(4) To evaluate the efficacy of procedures used in the various steps of the program, namely: (a) the identification of concepts; (b) their arrangement in a sequence that is scientifically sound and psychologically effective; (c) conducting an experimental teaching program in a selected school system; (d) designing appropriate, valid, and reliable testing instruments; and (e) the selection of personnel to develop and to teach the program.

(5) To identify problems that are encountered by elementary school teachers who attempt to use such a conceptually oriented program in science, particularly as these problems have implications for teacher training programs.

Each of the above-mentioned objectives and the steps taken to achieve them in the pilot study are discussed in detail in the following sections of this report. The last two sections of the report represent the findings of the study, with recommendations for future use of the materials and for further curriculum development along these lines.

METHODS

This chapter is organized in three parts to describe the various methods used in the overall pilot study. The first part deals with the methods employed in developing and revising the curriculum materials. The second describes the pilot teaching program that was conducted in two elementary schools and the testing program that was carried out to evaluate the effects of the teaching program. In the third part, the hypotheses of the study are identified, and the methods used to test them are described.

Developing the Curriculum Materials

A variety of methods was used as this two-year pilot study progressed from the selection of the conceptual scheme to the final testing of materials designed to teach it.

Exploration of the Sciences

The first task was to identify some of the specific concepts related to the major conceptual scheme, conservation of energy. This task was initiated by inviting a physicist, a biologist, two chemists, a geologist, and a mathematician to indicate ways in which the conservation principle is related to and can be demonstrated in their respective fields. The results of their efforts were reported and discussed by them during a two-day work conference in which a psychologist, a specialist in elementary science, and a science educator also took part. The conference yielded approximately 30 suggested demonstrations, most of which came from physics and chemistry. Virtually all of the suggestions from geology and biology were ultimately considered to be too sophisticated and remote from everyday experience for development in an elementary science curriculum.

Development of Teaching Materials

Regular members of the COPES staff then took these suggestions and began the task of developing teaching materials suitable for use in elementary school science. The pertinent literature was also reviewed for additional suggestions.

Preliminary Try-outs in Local Schools. From the beginning it was realized that children would be needed to assist in determining the instructional feasibility of the materials as they were being produced. Arrangements were made to work with children in two nearby elementary schools in New York City. Schedules were established in each school during which time selected classes of children were available to work with one or more members of the COPES staff. Tape recordings were made of some of the earlier sessions with children, but taping was discontinued in favor of anecdotal accounts of what took place. These accounts were dictated immediately after each session and made available to all members of the staff.

The COPES Laboratory School. Although most of the spring semester of 1966 was spent in devising materials, trying them out with children, and then revising them, it soon became evident that children would be needed during the summer when schools were closed. This led to the organization of a COPES laboratory school. Twenty-two children, ranging in age from 9 to 12 years, were enrolled in the laboratory school during July and August.

A science teacher was employed to carry on a regular science program for the children. Selected elementary science materials from ESI were used in the program. It was understood by both the teacher and the children that children would be taken out of the regular program whenever needed to work with the COPES staff. The plan worked exceedingly well and greatly facilitated the production of teaching materials. However, at the end of the summer not all of the proposed materials had been completed. It was therefore necessary to organize another laboratory school during the fall semester. About ten children attended the COPES science classes for one hour on Tuesday and Thursday afternoons.

Preparation of The Teacher's Guide. Periodically during the time when they were being prepared, teaching materials were reviewed by the scientist group referred to earlier, as well as by the regular members of the COPES staff. The scientists reviewed them primarily to pass judgment on their scientific accuracy and their pertinence to the conservation of energy principle. The staff reviewed them in terms of logical development and teachability. There were numerous staff consultations on each set of instructional material as it was being developed.

In the final stages of writing the teaching materials, an effort was made to use a format and a writing style that would communicate well with teachers. In this stage, the materials became known as The Teacher's Guide. Introductory material was prepared for each major section of the guide. Ten major concepts and the supporting concepts for each section were presented. Activities designed to teach the concepts were presented in considerable detail.

Preparation of Special Equipment. A set of equipment was designed for teaching certain activities in the mechanical energy segment of the sequence. Thirty-two of the sets were fabricated for use in the pilot teaching program. (See Appendix C for a description of the equipment.)

Identifying the Concepts

In planning the pilot study it had been assumed that, once the conceptual scheme of energy conservation was selected, the next logical task would be to identify the pertinent concepts in the scheme. But this is not the way it actually happened. The concepts were not easily identifiable until the learning activities began to emerge. For example, it was decided rather early that a sequence of activities should be designed to demonstrate conservation of thermal energy when specific volumes of water at specific temperatures were mixed. It was not until this sequence of activities was produced that the concepts involved could be clearly formulated into declarative sentences. The same situation was encountered in practically every other sequence of activities. After the concepts were identified and formulated, they were checked for scientific accuracy by the scientist group. (See Appendix B for the concepts thus identified.)

Designing and Evaluating the Sequence

Preliminary Investigation. Originally it had been planned that there would be three segments to the conservation of energy teaching sequence. One was to deal with thermal energy, the second with mechanical energy, and the third with electrical energy. As the result of a number of efforts to develop suitable activities dealing with electrical energy, it soon became evident that a segment dealing with electrical energy would depend on the support of certain other conceptual schemes. Thus, thermal energy and mechanical energy became the two principal segments of the teaching sequence.

It was in the task of designing the present sequence that the services of the COPES psychologists were found to be most helpful. They assisted by working with the developers of the activities in analyzing each concept, determining what was involved in learning it, and ordering the concepts in a sequence where an understanding of each successive concept depended on an understanding of preceding ones.

The Thermal Energy Segment of the Sequence. By July, 1966, the preliminary design for the heat energy segment of the teaching sequence had been developed and was ready for try-out with the children in the COPES laboratory school. These try-outs were conducted by one of the elementary science consultants from the Great Neck schools, who had joined the staff for the summer.

During the time the science consultant was teaching, the staff scientist, who had most to do with developing the heat energy materials, observed and assisted him. Notes were kept, and immediately after each session with the children, the teacher dictated his comments about the session. These records were later used in revising the teaching materials and the design of the sequence.

The Mechanical Energy Segment of the Sequence. Concurrently during the summer other members of the COPES staff tried out certain parts of the mechanical energy segment of the sequence with a small group of children from the laboratory school. Since the mechanical energy segment had not been developed as far as the thermal energy segment, further refinements and try-outs of it were carried out with children in the fall session of the laboratory school. The procedures followed were comparable to those used during the summer session.

Presequence Materials. As work progressed on the main teaching sequence, it became increasingly evident that children in the earlier grades of the elementary school would have to develop certain notions about time, space, motion, forces, and states of matter as preparation for the main sequence. Thus, an effort was initiated during the spring of 1966 to develop appropriate teaching materials for this purpose. As the materials were produced, some were tried out by the COPES staff with children in the kindergarten, first, and second grades in one of the local cooperating schools. Detailed records were kept of these experiences and used later in revising the materials. These materials became known as the Presequence and were considered appropriate for grades K, 1, and 2. In preparing the presequence activities, an effort was made to arrange them in a sequential order based upon estimated levels of difficulty. However, there was no opportunity to try out the completed sequence with children in a classroom situation prior to testing the program in the Great Neck schools.

Revision of Teaching Materials

During July and August, 1967, two regular members of the staff and one of the science consultants who taught the COPES materials revised them and rearranged the teaching sequence, when it seemed appropriate, into a more defensible sequence based upon reactions of teacher-observers and upon the experience of the teaching consultants. These revisions were reviewed and discussed by the entire COPES staff prior to the final writing of The Teacher's Guide. The revision has been done with the expectation that this teaching sequence will eventually be incorporated and integrated into an elementary science curriculum based on a number of conceptual schemes.

The Pilot Teaching and Testing Program

A pilot teaching program was carried out in two elementary schools in Great Neck, New York, from February, 1967 until the close of school 16 weeks later. A testing program to assess children's understandings of the science concepts that were taught was conducted in conjunction with the teaching program. The test results and the reactions of teacher-observers and teaching consultants provided a basis for evaluating the teaching materials.

Purposes of the Pilot Teaching Program

The purposes of the pilot teaching program were to determine: (1) if elementary school children gain in their understanding of the concepts with which the materials deal; (2) at which successive grades (K-6) various levels of the sequence are most appropriate; (3) whether the tests are suitable for various grades; (4) if the teaching materials would be generally usable by elementary school teachers; and (5) where the teaching materials should be further revised.

The Pilot Teaching Situation

Great Neck, a suburb of New York City, is considered to be an upper-middle class commuter community located in Nassau County on Long Island, and it is generally accepted that the Great Neck Board of Education maintains one of the best school systems in the county. In the eleven elementary schools, an effort is made to limit class enrollment to 25 children. Classes are taught in self-contained classrooms; and consultants in special subjects, such as science, are available in each elementary school to work with teachers. The two schools involved in this study were considered to be typical of the Great Neck elementary schools.

Under normal conditions, approximately 120 minutes per week are given to the study of science in grades 2 through 6. During the testing of the COPES materials, the time spent on science in the experimental classes was stepped up approximately 30% in the two schools. In order to complete the sequence in one of the schools, the fifth and sixth grades were taught science for 350 minutes a week during the last three weeks of school.

In each of the two schools one class from each grade, kindergarten through sixth, was used as the experimental group. Another class from each grade was used as the control group. Because the Great Neck schools assign children to classes on a heterogeneous basis, it is assumed that the experimental and the control classes were basically equivalent. The COPES teaching materials were introduced into the regular program of science studies of the experimental group of classes. The control group continued with its regular program of science studies uninterrupted.

This was not an experiment to compare one method of teaching elementary school science with another. The control group was used merely as a comparative reference to determine whether the experimental group would, in fact, realize significant achievement in science as a result of being taught with the COPES materials.

The elementary science consultant-teacher in each school devoted full-time during the 16-week period to teaching the COPES materials to the experimental classes in his school. During the preceding semester, the consultant-teachers were retained as part-time members of the COPES staff. They worked at the COPES center once a week, where they consulted on the development of materials. Thus, they became acquainted with the purposes of the project and with the teaching materials produced by it.

Plans for Teaching the Sequence

The original plan was for consultant-teachers to start each class (K-6) with the Presequence and take it as far as it could reasonably go in the main sequence. It was anticipated that both sixth grade classes would complete the entire sequence and that the kindergarten, first, and second grades in both schools would at least be taught the Presequence. In only one school, however, were the kindergarten and first grade classes taught the Presequence. Only one sixth grade class completed the entire sequence. Thus, at least one class in each grade (K-6) was taught with the COPES materials in one school or the other.

Provisions for Teachers' Evaluations

The classroom teacher in each experimental class cooperated by critically reviewing the materials in The Teacher's Guide, by observing each lesson as it was taught by the consultant-teachers, and by writing an analytical evaluation of the materials and the lesson after it was taught. Standardized, one-page schedules were used by each teacher in reporting her evaluations and observations. (See Appendix D.)

The teachers' reactions sheets were carefully examined by the COPES staff and tabulated. These data were used during the summer of 1967 in revising the teaching materials and in deciding at which grade levels each section of the sequence appears to be most appropriate.

Near the conclusion of the trial-run period in Great Neck, the COPES staff met again with the two teaching consultants and the 14 elementary school teachers whose classes comprised the experimental group. At this meeting the teachers were encouraged to present their general impressions of the materials, to react to what they had observed in their classes, and to indicate what problems they might encounter if they were asked to teach the materials. A stenographic record was kept of the conference, and it was used in arriving at certain of the results, conclusions, and recommendations reported later in this document.

At the end of each day's work with the children the teaching consultant reported, by using a portable tape recorder, his impressions of the lessons he had taught and of the suitability of corresponding teaching materials and equipment. The transcripts of these tapes were made available to all members of the staff for their consideration in revising the materials.

The Testing Program

From the beginning of the pilot study certain members of the staff were concerned primarily with assessing the achievement of children who are taught with the COPES materials. Although the teaching materials involve children in processes of investigation, the primary objective was concept development. Thus, the task of evaluation included the development of testing instruments to assess children's understandings of the concepts with which the sequence deals. Two tests were developed, each one dealing with one of the types of concepts mentioned below.

The COPES Test of Critical Terms. A test was developed that deals with terms considered to be critical to the understanding of concepts in the conservation of energy sequence. These concepts can be represented by words such as speed, melt, solid state, balanced, kinetic energy, evaporate, and work. The test consists of 46 items, 32 of which are picture items and 14 of which are sentence choices. (A copy of the test and an account of how it was developed are included in Appendix E.)

The COPES Test of Science Concepts. By the method described earlier, ten major concepts were identified. For each of the major concepts, a number of supporting concepts were also identified.

To assess children's understandings of the major concepts, it was decided to use Suchman's Predict-Control-Explain test model.[2] The test consists of ten problem situations, each of which has three multiple-choice items: one item has to do with making a prediction; another item deals with controlling some action in the problem situation; and a third item involves an explanation for the prediction and the control. Thus, the entire test contains 30 test items. (A copy of the test and an account of how it was developed are included in Appendix E.)

Scoring the Tests. A score for each of the two tests was obtained by assigning one point for each test item correctly marked.

Administration of the Tests. With the exception of kindergarten and first grade in one school, the COPES Test of Critical Terms was given to all children in both the experimental and the control classes as pre-tests and as post-tests. The teaching consultant, assisted by the regular classroom teacher, administered the pre-test. The regular classroom teacher administered it as a post-test.

The COPES Test of Science Concepts was given only as a post-test and only to fourth grade classes and above in the experimental group and to their counterparts in the control group. The test was administered by the regular classroom teachers. Since classes varied in the extent to which they progressed through the sequence of materials, they were given only those parts of the test that deal with the concepts taught to the class.

Both tests were read aloud to all classes while the children read them silently and then recorded their responses. This was done in an effort to compensate for differences in children's reading abilities.

Reliability of the Tests. The reliability of each of the two tests was determined for each grade level by the split-half method and the Kuder-Richardson Formula 20.[3] Two halves were obtained for the COPES Test of Critical Terms by categorizing the test items after the pre-test administration into two halves based on equivalence of content. The two halves thus obtained were assumed also to be equivalent in level of difficulty. (See Appendix B, p. 6.)

Two halves were obtained for the COPES Test of Science Concepts after it was administered by separating the test items so that all odd-numbered items were placed in one half and the even-numbered items in the other half. The two halves thus obtained were assumed to be equivalent in both content and level of difficulty.

[2]Richard J. Suchman, The Elementary Science Training Program in Scientific Inquiry, University of Illinois, 1961. U. S. Office of Education, Project No. 216.

[3]J. P. Guilford, Psychometric Methods (New York: McGraw-Hill Book Company, 1954), p. 380.

A half-test coefficient was obtained for each of the two tests by correlating the scores on the two halves. To estimate the reliability of each of the two whole tests, the half-test coefficient was corrected by the Spearman-Brown prophecy, or step-up formula.[4]

Methods for Analyzing Test Results

Various methods were selected for analyzing the results of both the COPES Test of Critical Terms and the COPES Test of Science Concepts. The particular methods were chosen to test four hypotheses regarding pupil achievement in a teaching program using the COPES materials.

Hypotheses to be Tested

Hypothesis 1

The mean of the post-test scores on the COPES Test of Critical Terms for classes in the experimental group in each school will be greater than the mean of the post-test scores of classes in the control group in the same school. This difference will hold for separate grade levels.

Hypothesis 2

The difference in the means of post-test scores on the COPES Test of Critical Terms of any two successive grade levels in the experimental group in each school will be greater than the difference in the means of the post-test scores of the two corresponding grade levels in the control group in the same school.

Hypothesis 3

The mean of the scores on the COPES Test of Science Concepts for classes in the experimental group in each school will be greater than the mean of the scores for classes in the control group in the same school. This difference will hold for separate grade levels.

Hypothesis 4

The difference in the means of scores on the COPES Test of Science Concepts of any two successive grade levels in the experimental group in each school will be greater than the difference of the means of scores of the corresponding grade levels in the control group in the same school.

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[4]Merle W. Tate, Statistics in Education (New York: The Macmillan Company, 1965), p. 187.

Methods Used to Test the Hypotheses

Differences among groups that are compared are reported as non-significant or as significant at either the .05 or the .01 level.

To test Hypothesis 1, the significance of the overall difference between the means of the post-test scores of the experimental group and the control group were determined by using analysis of covariance in order to adjust the scores of the two groups for differences in pre-test scores. When the overall difference was found to be significant, a posteriori comparisons[5] (pair-wise) were made to test the significance of the difference between the means of scores of the experimental group and control group at each grade level in each of the two schools. The procedure of a posteriori comparisons was also used to test Hypothesis 2.

It was planned that if the overall difference between the experimental and the control group was not significant, analysis of covariance would be used to test the significance of the overall difference between the means of the scores for grades one through three in the experimental group in each school with the means of scores for corresponding grades in the control group in each school. (This procedure was planned to cover the possibility that the test ceilings might be too low to allow real treatment effects to be reflected in test scores of the higher grades.) Since this difference was found to be significant, a posteriori comparisons (pair-wise) were made to test the significance of the difference between the means of scores of the experimental and control groups at each grade level (1-3) in each of the two schools. The procedure of a posteriori comparisons was also used to test Hypothesis 2 for grades one to three.

To test Hypothesis 3, the significance of the overall difference between the means of scores of the experimental group and the control group was determined by factorial analysis of variance for grades four, five, and six. When the overall difference was found to be significant, the Scheffé method[6] was used to test the significance of the differences between the means at each grade level represented. The Scheffé method was also used to test Hypothesis 4.

[5] B. J. Winer, Statistical Principles in Experimental Design (New York: McGraw-Hill Book Company, 1962) p. 598.

[6] Ibid., pp. 209-211.

RESULTS AND DISCUSSION

In this pilot study ten major concepts were identified that relate to the conceptual scheme dealing with conservation of energy. For each major concept a number of supporting concepts were identified. Learning activities to teach the supporting concepts were produced and organized into a hierarchical sequence. A teacher's guide to be used in directing the learning activities with children was prepared.

The teaching materials were tested in two elementary schools, from which were obtained feedback from teachers and assessments of pupil achievement.

Learning Activities Dealing with the Conservation of Energy

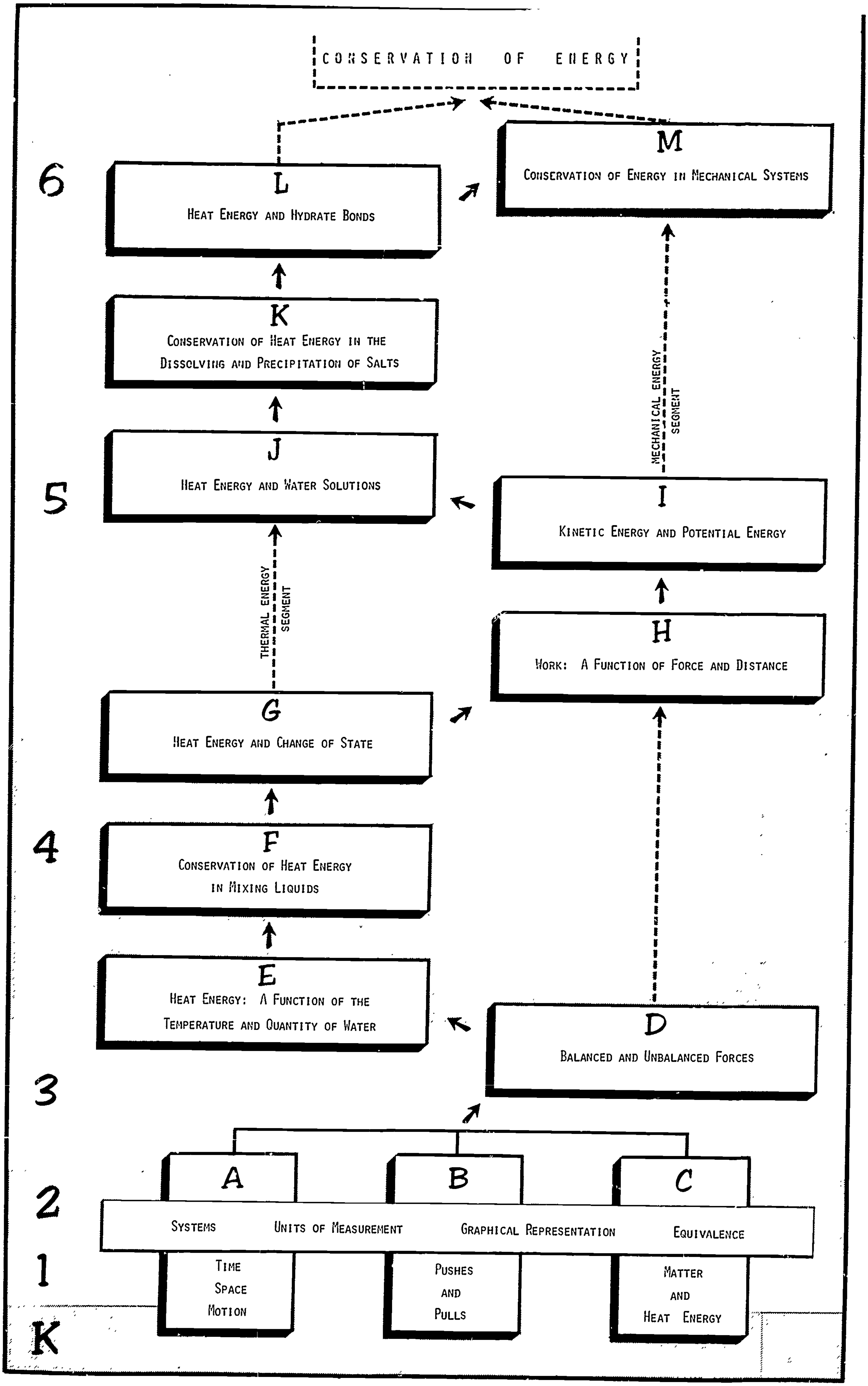
The Concepts

A number of concepts are involved in the development of a progressively sophisticated understanding of conservation of energy. Some may be represented by such terms as temperature, volume, heat, state of matter, and change of state. These were considered to be critical for an understanding of other concepts with which the sequence deals. In the learning activities developed during the pilot study, 47 such basic concepts, or critical terms, were identified, and are listed in Appendix B.

Involved also is another type of concept that deals with relationships among certain of the basic concepts. One such concept deals with the relationship of the heat energy of a liquid system to the amount of liquid contained in it and the temperature of the liquid. This relationship may be expressed as: "The heat energy of a liquid system depends upon the amount of liquid and its temperature." Ten major concepts of this type were ultimately selected as the concept objectives of the main teaching sequence in the pilot study. Six of them deal with thermal energy and four with mechanical energy. The ten major concepts, along with their supporting concepts, are presented in Appendix B.

The Scope and Sequence

The chart on page 13 was prepared to represent the scope of the concepts and related learning activities with which the materials in the pilot study deal and the instructional sequence into which they were finally organized. The rectangles, identified by letters from A to M, represent the different sections for which learning activities were produced. The title of each section indicates the principal focus of its learning activities. Solid arrows indicate the direction in which the learning sequence progresses and the dashed arrows show the two major segments of the sequence--thermal energy and mechanical energy.



CONSERVATION OF ENERGY
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L
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M
CONSERVATION OF ENERGY IN MECHANICAL SYSTEMS
K
CONSERVATION OF HEAT ENERGY IN THE DISSOLVING AND PRECIPITATION OF SALTS
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Before beginning the main sequence at D, it was considered desirable that children have some notion about the concepts listed in A, B, and C. As the chart indicates, notions regarding systems, units of measurement, graphing, and equivalence were also considered as prerequisites. The teaching materials that were produced to develop these notions have been referred to as the Presequence, a nomenclature that refers to the learnings that are considered as prerequisite to the main sequence.

Although the main sequence begins with Section D as an introduction to forces, the activities and concepts dealing with conservation of energy actually begin with Section E. The activities in Section E, F, and G have been prepared to deal in a progressive manner with heat energy and its conservation in liquid systems. The activities in Sections H and I introduce the concepts of work, a work unit, potential energy, kinetic energy, and the interconversion of these forms of energy. This is done as preparation for teaching the concept that heat energy does work in the formation of salt solutions in water (Section J). The activities in Sections J, K, and L deal in a progressively sophisticated manner with the conservation of heat energy in the heat energy exchanges that take place in activities dealing with solutions, supersaturated solutions, and hydrated salts. The activities in Section M have been designed to build upon previously developed concepts dealing with mechanical and thermal energy and to lead ultimately to the conservation of energy concept.

It will be noted that there are two segments to the main conservation of energy sequence as developed in this pilot study. One segment deals with developing the idea of conservation of heat energy and the other with developing the idea of conservation of mechanical energy. In several activities in Section M, the interrelationships between heat energy and mechanical energy in a mechanical system are introduced. It was anticipated that children who were taught by these materials would discover the interrelationship between the two. As will be shown later, this is what actually happened.

Teaching Materials

The teaching materials include descriptions of pupil activities that direct learning from kindergarten through grade 6 along the scope-and-sequence development described above. These materials represent the most important product of the pilot study. In their original form they were incorporated into a teacher's guide that was used in the pilot teaching program in the Great Neck schools. Based upon feedback from the schools, the materials have been thoroughly revised and have been published separately from this report as The Teacher's Guide for a Conservation of Energy Sequence.

The introduction to the guide includes a general discussion of the rationale of the conceptual schemes approach, an explanation of the manner in which the guide is organized, and general suggestions for its use. The guide is divided into two parts, the Presequence (Sections A, B, and C of the Scope and Sequence) and the main sequence materials (Sections D through M of the Scope and Sequence).

The Presequence includes 46 learning activities dealing with time, space, motion, forces, states of matter and heat energy. The presequence activities have been found to be effective in preparing children to begin the main sequence, and these are recommended for use in the first three grades (K-2). The grade levels at which the individual activities have been found to be most appropriate are indicated in The Teacher's Guide.

In the introduction to the Presequence, the general purposes to be accomplished by the activities are explained to the teacher. The activities are numbered sequentially and each has been given an appropriate title. Each activity is introduced with a statement of its specific purpose, a list of needed materials, and instructions on how to prepare for the activity. This is followed by detailed suggestions for carrying out the activity with children. Diagrams have been included wherever they are needed to make the instructions clear.

The main sequence is divided into ten sections. Each section has been assigned an identifying letter corresponding to the section in the scope and sequence development where its learning activities apply. The activities in each section of the main sequence have been developed to direct the learning of children toward an understanding of one of the ten major concepts. Each section is headed with a statement of the major and supporting concepts to which the activities in the section relate. In each sectional introduction, the teacher is informed how the concepts to be developed in that section are related to those developed in earlier sections and how they, in turn, lead into the concepts developed in subsequent sections. The format for presenting the activities is similar to the one used for the presequence activities. There are about 75 activities in the various sections of the main sequence.

An inventory of the materials and supplies needed in this program is included in the appendix to The Teacher's Guide for a Conservation of Energy Sequence. The inventory is divided into three categories: 1) materials and supplies that must be obtained from scientific supply houses; 2) materials and supplies that can be obtained locally; 3) materials and supplies to be prepared by the teacher. The specifications for a kit of equipment, which was devised and found to be useful in performing certain experiments in mechanical energy, are also included in the appendix. A brief description is also included in Appendix C to this report.

During the production and refinement of the above activities and the ordering of them into a developmental learning sequence, several things happened that seem appropriate to mention here. Before many of the main sequence activities had been tried out with children, it had been assumed that concepts and related activities in mechanical energy would be most suitable in demonstrating the conservation principle and, therefore, would have a prominent place, if not a fundamental one, in the main sequence. It was further assumed that heat energy would play a less prominent role in the sequence. But just the reverse was found to be the case. In preliminary try-outs with children from a local elementary school, and later with children in the COPES laboratory school, the activities and concepts dealing with conservation of heat energy were found to be a more feasible introduction to the main sequence than those dealing with conservation of mechanical energy. Heating, cooling, and measuring of quantities and temperatures of liquids seemed to be conceptually more manageable for children than forces and motion. The concept of a "heat energy unit," which was fundamental to understanding the conservation of heat energy, seemed initially to be less abstract to children than that of work, a concept needed to deal with conservation of mechanical energy.

The psychological appropriateness of introducing experiences with heat energy early in the main sequence, bringing in the experiences with mechanical energy later, then going back to heat energy was verified by the results. One of the teaching consultants found that upper grade children readily discovered the interrelationships between mechanical energy and thermal energy.

Based upon the results of the pilot-run of the presequence materials in the Great Neck schools, it was possible to determine at which grade level each of the activities was most appropriate. However, it was not possible to organize the Presequence into a tight, sequential structure in which each activity was built on the one preceding it and was prerequisite to the one following it. But there are clusters of interdependent activities in the Presequence for which a sequential arrangement was appropriate, even though no rationale could generally be found for arranging the clusters in a sequential order.

Eventually in the total COPES curriculum, sequences for several conceptual schemes will be developed. For each of these, there will be other notions that children should have before beginning their study of that sequence. Presequence teaching materials will be produced to develop these ideas. It is anticipated that, when this is done, a rationale for a sequential arrangement of these activities may be identifiable.

Pilot Teaching in the Schools

Several problems were encountered in the pilot-run of the COPES materials in the Great Neck schools. It had been planned that all grades (K-6) would be taught the materials and that each grade would proceed as far as it appeared capable. Since it was not possible to check out the Presequence in the COPES laboratory school, it was not possible to predict accurately the time it would take to teach the activities in it at the different grade levels. Further, the teaching consultants had not been instructed regarding the relative amount of time to be spent on the different activities at any grade before a decision should be made regarding its suitability for that grade level. This resulted in an excessive amount of time being spent on certain activities in the Presequence and delayed the starting time for teaching the main sequence.

Classes Taught with the Materials

For reasons mentioned above, it was not possible to teach the materials to all classes in both schools as had been originally planned. However, it was possible to adjust the teaching schedules so that in one school or the other, at least one class at each grade level progressed as far through the sequence as the class was judged to be capable.

One kindergarten class, one first grade, two second grade, and two third grade classes completed all of the presequence activities judged to be appropriate for their respective grades. In the fourth, fifth, and sixth grades only those presequence activities were taught that dealt with concepts that these older children, in the opinion of their teachers, had not developed in the earlier grades. This resulted in the upper grades being taught only selected presequence activities, about one-half of the total number.

One third grade class completed several activities in the first mechanical energy section of the main sequence (Section D) and the other third grade class completed many of the activities in the first section of the thermal energy sequence (Section E). The two fourth grade classes completed about one-third of the main sequence. One fifth grade class completed about one-half on the sequence and the other one completed about two-thirds of it. One sixth grade class completed the entire main sequence, whereas the other sixth grade class completed only one-half of it.

Teachers' Evaluations of the Pilot Teaching Program

Reactions to the program were obtained from regular classroom teachers and the two teaching consultants. The reactions of classroom teachers can be summarized as follows:

(1) Children were generally enthusiastic about the experiences provided by the COPES teaching materials. They particularly liked the opportunities to investigate on their own.

(2) Most teachers liked the highly structured manner in which the sequence of materials was organized. However, some felt that it restricted opportunity for exploration to which their children had become accustomed in science.

(3) They generally agreed that the investigations conducted by children "opened their eyes to what nature is and how it works."

(4) None of the teachers believed that she could have taught the material before observing the teaching consultants work with the children. Most of them felt they would need a good deal of in-service preparation before attempting to teach the main sequence. A few reported that they would probably never be able to teach such sophisticated science.

In reacting to individual learning activities, the classroom teachers identified a number of places where changes in the materials would be desirable. These had to do with vocabulary, grouping of children, development of prerequisite skills, reducing required preparation time for the teacher, motivation, clarity of directions, and provisions for individual differences. Many of these suggestions were found helpful in revising the materials. From certain of their reactions to the main sequence materials, it could be inferred that some of the regular classroom teachers did not understand the concepts that were being developed.

The reports that were found to be most revealing and helpful were those given by the teaching consultants. In a general reaction to the program, one of the teaching consultants had this to say:

The older children noticed the cohesiveness of the whole sequence. They noticed that the ideas we were discussing at one level were similar to, and grew out of, topics they had studied at a prior level. They could see the sequential progression of ideas and could see how the smaller ones contributed to the bigger ones.

The notion of heat energy conservation began to emerge with fourth grade children toward the end of Section F, but they were unable to verbalize the concept clearly. Toward the end of the pilot teaching program, the sixth grade children verbalized their understandings of the interrelationships between mechanical energy and thermal energy. In several cases, they suggested analogies between what they had learned in the thermal energy activities and phenomena that they observed in the mechanical energy activities. For example, they first achieved the notion of conservation in the the thermal energy sequence, and, as they began to explore the interchangeability of potential and kinetic energy, they frequently fell back on the analogy of heat energy and said it was the same kind of thing.

Although there were spots in the sequence that were difficult to maneuver, the children seemed to recognize the simplicity and the coherence of the whole scheme. The transitions in helping children achieve an understanding of the convertibility of forms of energy was not easy. Some of the specific activities require revision to make them more teachable and to improve the coherence of the entire sequence.

The structure of the sequence enabled a few children to make sudden conceptual "leaps" that projected them quite a bit ahead in the sequence. Somehow they got a tip-off! They also recognized, and said so, that most of what they learned came through their own efforts and discovery.

Both teaching consultants reported on their experience with each activity at each of the grade levels where it was taught. They made judgments regarding their success in using the activity with children at various grade levels. They pointed out specifically those parts of the activity that worked well, and those that did not. They frequently explained why the results of an activity turned out as they did. In many instances they suggested ways in which activities could be improved and/or supplemented to produce the desired learning outcomes. Frequently they reported instances where their children lacked the conceptual background to undertake certain activities and indicated how they compensated for this deficiency. Where children lacked the skills needed in certain activities, the teaching consultants explained how they taught them. They reported on the failure of certain equipment to work as had been intended, and suggested ways of modifying it. The suitability of various materials, such as graph paper, was evaluated. They often mentioned specific responses of children about their experiences with certain activities. In every instance, their reporting yielded evidence that could be used in judging the appropriateness of the activity for use at various grade levels in their schools. The teaching consultants' reactions to the materials were found most useful in revising them. One of the teaching consultants worked with the staff full-time during the summer of 1967 on the revision of the teaching materials.

Some of the classroom teachers and the teaching consultants also reacted to COPES Test of Critical Terms and the COPES Test of Science Concepts. Most of their reactions to the COPES Test of Critical Terms dealt with specific items and were relatively minor. However, the reaction of classroom teachers to the COPES Test of Science Concepts clearly indicated that the entire test disturbed them. Both the format of the test and the substantive nature of it were new to them. In light of the fact that elementary science teachers assisted in the preparation of both of the tests, one possible explanation for this reaction is that these classroom teachers were unfamiliar with the concepts with which the tests deal and with the processes involved in taking the tests.

Results of Test Analyses

The four hypotheses, stated on page 10, predicted the achievement of children as assessed by two instruments: The COPES Test of Critical Terms and the COPES Test of Science Concepts. The reliability coefficients and the standard errors of measurement of the tests are reported immediately below. The analyses of test data that were used to test the four hypotheses are reported in the subsequent section.

Reliability and Standard Error of Measurement

The reliability estimates by grade level (K-6) for the COPES Test of Critical Terms are reported in Table I. It will be noted that reliability estimates tend to decrease from the lower to the higher grade levels. In part, this can be accounted for by the fact that in the higher grades the mean scores on this test tended to approximate the maximum score. It will also be noted that the standard error of measurement becomes less from lower to higher grade levels. This is partly accounted for by the fact that the variability tended to be less at the upper grade levels.

Table I

Reliability Estimates for the COPES Test of Critical Terms by Grade Levels

Grade	Reliability Coefficients*		Standard Error of Measurement
	Split-half	K-R (20)	
K**	.847	.863	2.51
1	.504	.542	2.80
2	.615	.593	2.47
3	.513	.439	2.28
4	.323	.412	2.48
5	.597	.532	1.94
6	.589	.431	1.72

*Significant at the .0025 level.
**Took only the first part of the test consisting of 32 items.

The reliability estimates by grade levels for the COPES Test of Science Concepts are reported in Table II. Scores for each grade level from the two schools were not combined because different numbers of items were given at different grade levels in each school. Classes below the fourth grade did not take the test. The highest reliability was obtained for the sixth grade in School II. This was the class that completed the main sequence and took the entire test with a maximum score of 30 points. Reliability estimates for the other grades are based upon a maximum score of fewer points, as indicated below Table II. There was a tendency for both the reliability estimate and the standard error of measurement to increase from fourth grade through sixth grade.

Table II

Reliability Estimates for the COPES Test of Science Concepts by Schools and Grade Levels

School	Grade*	Reliability Coefficients**		Standard Error of Measurement
		Split-half	K-R (20)	
I	4	.47	.55	1.36
	5	.63	.64	1.53
	6	.66	.61	1.18
II	4	.22	.28	1.25
	5	.70	.61	1.66
	6	.83	.84	2.26

* Maximum score for fourth grades was 9 points; for fifth and sixth grades in School I, it was 12 points; for the fifth and sixth grades in School II, it was 21 points and 30 points respectively.

** Except for grade 4 in School II, all coefficients are significant at the .0025 level.

Tests of the Hypotheses

The test score data that were used in the investigation of the four hypotheses are reported in Tables III-VIII. The analysis of covariance for the COPES Test of Critical Terms is summarized for each school separately in Table III. As indicated earlier, test results for grade six in both schools were not used here since the mean scores for that grade tended to approximate the maximum score on this test. Test data for kindergarten and grade one in School II are not included because they were not given the post-test. Kindergarten in School I was omitted because it took only a part of the test. It will be noted that the F-ratio for between treatments (experimental and control) is significant at the .01 level for each of the two schools. This finding supports 1.

Table III

Summary of Analysis of Covariance* for the COPES Test of Critical Terms

School	Source	Sum of Squares	DF	Mean Square	F	p
I	Treatments (A)	179	1	179	30.9	.01
	Grades (B)	255	4	63.8	11.0	.01
	Interaction (AxB)	106	4	26.5	4.6	.01
	Error	1031	179	5.8		
II	Treatments (A)	91	1	91	13.6	.01
	Grades (B)	125	3	41.7	6.2	.01
	Interaction (AxB)	21	3	7	1.04	N.S.
	Error	853	127	6.7		

*Based on 19 cases for each grade in School I and 17 cases for each grade in School II.

Table IV

Comparison of the Adjusted Post-test Means of Scores on the COPES Test of Critical Terms for the Experimental Group with Those for the Control Group by School and Grade Level

School	Grade	Adjusted Post-test Means		Pair-wise
		Experimental	Control	Comparison
I	1	32.16	32.98	N.S.
	2	35.48	33.22	.01
	3	37.92	34.28	.01
	4	37.61	35.49	.01
	5	38.06	35.50	.01
II	2	36.62	35.34	N.S.
	3	38.28	37.40	N.S.
	4	38.28	36.90	N.S.
	5	40.88	37.94	.01

Since the F-ratio for between treatments was significant, pair-wise comparisons of the adjusted post-test means of scores for the experimental group with those for the control group by school and grade level were carried out. The results are reported in Table IV. Out of five comparisons in School I, four were significant at the .01 level. Out of four comparisons in School II, one was significant at the .01 level.

To test Hypothesis 2, a posteriori comparisons were made of the difference between the adjusted post-test means of scores at successive grade levels in the experimental group with the difference between those at successive grade levels in the control group. The results of these comparisons are reported in Table V. It will be noted that none of the comparisons is significant. This was followed by planned comparisons[7] among those in each school that were found to be independent of each other. This results in comparisons between grades one and two, and between grades three and four in School I. In School II the independent comparisons were made between grades two and three and between grades four and five. In one of those four comparisons,between grades one and two in School I, the result was significant at the .01 level.

Table V

Comparisons of the Difference Between the Adjusted Post-test Means of Scores on the COPES Test of Critical Terms at Successive Grade Levels for the Experimental Group With That for the Control Group

School	Grade	Adjusted Post-test Means		a posteriori
		Experimental	Control	test*
I	1	32.16	32.98	N.S.
	2	35.48	33.22	N.S.
	3	37.92	34.28	N.S.
	4	37.61	35.49	N.S.
	5	38.06	35.50	
II	2	36.62	35.34	N.S.
	3	38.28	37.40	N.S.
	4	38.28	36.90	N.S.
	5	40.88	37.94	

*Scheffé method

[7]William L. Hays, Statistics for Psychologists (New York: Holt, Rinehart, and Winston, 1963), pp. 462-483.

The factorial analysis of variance for the COPES Test of Science Concepts is summarized for each school separately in Table VI. It will be noted that the F-ratio for between treatments (experimental and control) is significant at the .01 level for each of the two schools. This finding lends support to Hypothesis 3. Since the F-ratio for between treatments was significant in both schools, *a posteriori* comparisons of the means of scores for the experimental group with those for the control group by school and grade level were carried out. The results are presented in Table VII. As was reported earlier, grade six in School II was the only grade that completed the entire sequence of instruction. They and their counterparts in the control group took the entire COPES Test of Science Concepts, consisting of 30 items. The fifth grade in School II took 21 items. In School I, the fifth and sixth grades each completed about one-half of the main sequence. They and their corresponding grades in the control group took only 12 items. The fourth grade experimental and control groups in both schools took only the first nine items. As shown in Table VII, only two of the comparisons in School I were significant at the .05 level. One comparison was significant at the .05 level in School II.

Table VI

Summary of Factorial Analysis of Variance*
for the COPES Test of Science Concepts

School	Source	Sum of Squares	DF	Mean Square	F	p
I	Treatments (A)	187.5	1	187.5	55.2	.01
	Grades (B)	160.1	2	80.0	23.6	.01
	Interaction (AxB)	20.2	2	10.1	3.0	N.S.
	Residual	387.4	114	3.4		
II	Treatments (A)	414.4	1	414.4	44.2	.01
	Grades (B)	3102.1	2	1551.0	165.4	.01
	Interaction (AxB)	203.3	2	101.6	10.8	.01
	Residual	1068.8	114	9.4		

*Based on 20 cases for each grade in each of the two schools.

Table VII

Comparison of the Means of Scores on the COPES Test of Science Concepts for the Experimental Group with Those for the Control Group by School and Grade Level

School	Grade	Means for Groups: Experimental	Means for Groups: Control	a posteriori test*
I	4	6.65	4.60	.05
	5	9.00	5.35	.05
	6	9.35	7.55	N.S.
II	4	6.25	5.40	N.S.
	5	13.90	10.75	N.S.
	6	21.85	14.70	.05

*Scheffé method.

To test Hypothesis 4, a posteriori comparisons were made of the difference between the means of scores at successive grade levels in the experimental group with the difference between those at successive grade levels in the control group. The results of these comparisons are reported in Table VIII. It will be noted that neither of the two comparisons in School I is significant. However, the comparison between grades five and six in School II was significant. Attention is called to the small difference (.35) between the means of scores for the experimental fifth grade and sixth grade in School I. This may be accounted for by the fact that each of these grades completed the same number of activities in the main sequence.

Table VIII

Comparison of the Difference Between the Means of Scores on the COPES Test of Science Concepts at Successive Grade Levels for the Experimental Group with the Difference Between those for the Control Group

School	Grade	Means for Groups		a posteriori
		Experimental	Control	test*
I	4 5 6	6.65 9.00 9.35	4.60 5.35 7.55	N.S. N.S.
II	4 5 6	6.25 13.90 21.85	5.40 10.75 14.70	N.S. .05

*Scheffé method

Summary of Test Results

Overall,the experimental group in each school did significantly better on the COPES Test of Critical Terms at the end of the instruction program than did the control group in the same school after adjustments were made for differences in pre-test scores. When class-by-class comparisons were made, more than one-half of the experimental classes did significantly better than corresponding control classes. There was, in general, an increase in the mean score of classes from one grade to the next in both the experimental and the control groups. The differences in post-test mean scores from one grade level to the next were generally higher in the experimental group than in the control group; however, none of the comparisons between experimental and control groups was statistically significant.

The COPES Test of Science Concepts was given as a post-test in grades four through six. Overall, the experimental classes in each school scored significantly higher on this test than did the control classes. Although every experimental class scored higher than the corresponding control class, the difference was statistically significant in only three out of the six comparisons. The increase in mean scores from grade level to grade level was greater for the experimental classes than for the control classes, except in one comparison. As had been anticipated, there was no appreciable difference between the mean scores of the fifth grade and those of the sixth grade in the school in which the sixth grade did not complete the entire program. In the school in which the sixth grade completed the entire program, the difference in mean scores between the fifth and sisth grades in the experimental group was twice the difference in mean scores between the fifth and sixth grades in the control group.

CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

The conservation of energy principle was selected as the conceptual scheme to be developed in this pilot study because it is one of the most fundamental and pervasive of all conceptual ideas in science. This was done to ensure that the pilot study would represent a rigorous test of the feasibility of a conceptual approach to elementary science curriculum development. The success of such an approach has been clearly demonstrated and thus has implications for further curriculum development.

We believe that the specific conclusions which follow are fully warranted by the results obtained in the pilot study:

(1) A conceptual scheme approach to elementary science curriculum development is entirely feasible. The evidence from this pilot study clearly suggests the validity of this major conclusion.

(2) Concepts dealing with the conservation of energy can be ordered into a hierarchical scheme that has both logical validity, as viewed by scientists, and instructional validity, as demonstrated by evidence obtained from working with children.

(3) A sequence of learning activities can be developed that enables children, from the early elementary grades through the sixth grade, to attain a progressively sophisticated understanding of the main concepts of this hierarchical scheme and to discover among those concepts relationships that contribute to an understanding of energy conservation.

(4) Many children, by the end of the sixth grade or earlier, can attain a reasonably sophisticated understanding of the conservation of energy principle.

(5) Statements by children in this pilot study and observations of their behavior by teachers suggest that, in general, they reacted favorably and with enthusiasm to a conceptual scheme approach that emphasized individual investigation and the discovery of relationships among concepts.

(6) Easily-scored paper-and-pencil tests can be constructed to yield evidence regarding children's understandings of concepts selected from various levels of a hierarchical scheme of concepts relating to the conservation of energy.

(7) Reactions from classroom teachers associated with this pilot study indicate that most elementary school teachers lack the background in science needed to handle these materials adequately.

The most significant implication of this study is the feasibility of developing materials which will contributed to children's understanding of other conceptual schemes in science. Further, the development of an entire elementary school science curriculum with a conceptual orientation would not only be feasible, but would give the curriculum a rational structure. There is good reason to believe that the concepts in a single conceptual scheme can be developed even more effectively within a total curriculum based upon a number of conceptual schemes that are mutually complementary. It is also clear that the average elementary school teacher will require special preparation in science before attempting to teach such a science program.

The success of the pilot study with only one conceptual scheme prompts us to make the following recommendations:

(1) In order that schools can be more effective in helping children become scientifically literate, a complete elementary school science curriculum based on a number of conceptual schemes should be developed.

(2) The present scope of efforts to improve elementary school science should be enlarged to include such a conceptual schemes approach.

(3) Preservice and inservice science courses based on a conceptual schemes approach should be developed as soon as possible to ensure that an adequate number of teachers are prepared to teach such a science program in the elementary schools.

SUMMARY

A conceptually oriented approach to teaching elementary school science has been tested by means of a pilot study dealing with a single conceptual scheme: the principle of conservation of energy. A complete set of materials was developed by a team of scientists and educators for teaching this conceptual scheme in sequential fashion from kindergarten through grade 6, including laboratory activities and materials, a Teacher's Guide and several objective evaluative instruments.

The program as developed turned out to be a highly structured, exploration and experiment-centered curriculum, requiring a fair degree of sophistication in science on the part of the teacher. Special preparation in science would be needed by the average elementary teacher to work effectively with this program.

The overall outcome of the pilot study was highly positive. The evidence clearly demonstrates that a conceptual scheme approach to elementary science curriculum development is entirely feasible. Classroom observations and test results revealed that children at successive grade levels were able to attain progressively sophisticated concepts leading toward an understanding of the conservation principle. Moreover, the impression is very strong that such an approach makes a substantial impact on children and hence may be more effective in teaching elementary school science than the conventional unstructured curriculum.

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APPENDIX A

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WITH THE
COPES PROJECT

PERSONNEL ASSOCIATED WITH THE COPES PILOT STUDY

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APPENDIX B

CONCEPTS DEVELOPED

IN THE

CONSERVATION OF ENERGY SEQUENCE

CONCEPTS IN THE COPES CONSERVATION OF ENERGY SEQUENCE

The following critical terms represent concepts, an attainment of which is considered essential to an understanding of the conservation of energy principle.

amount of stretch
(an) attractive force
balanced
binding force
change of state
(a) crystal
dissolve
(more) distance
energy
equal
evaporate
(a) force
friction
(a) gaseous state
(a) graph
(to) graph
gravitational field
greater than
heat energy
(a) heat energy unit
horizontal
kinetic energy
less than

liquefy
(a) liquid state
(more) measures
(a) melt
(to) melt
(a) mix
(a) model
(an) opposing force
(a) particle
potential energy
predict
solid state
solidify
(a) solution
speed
temperature
(a) thermometer
unbalanced
unequal
unit
vertical
weight
work

Major and Supporting Concepts

The following statements represent concepts that deal with relationships among certain of the more basic concepts.

I. A force is a push or a pull that, if unbalanced, moves an object from rest or changes the motion of a moving object. (Section D)

   a. There are several kinds and sizes of forces.

   b. An object does not move from rest when the forces acting on it are balanced.

   c. Weight is a measure of the gravitational force on an object.

II. The heat (thermal) energy of a liquid system is a function of the temperature and quantity of the liquid. (Section E)

   a. The temperature of a system depends on the heat energy it contains.

   b. When heat energy is added to a system, the temperature of the system may increase; and when heat energy is removed from a system, the temperature of the system may decrease.

   c. Heat energy of itself passes only from a system at a higher temperature to one at a lower temperature.

   d. The heat energy in liquid water can be measured by the rate at which the water can melt an ice cube.

   e. A liquid system at a higher temperature contains more heat energy than a system of the same liquid and volume at a lower temperature.

   f. A liquid system with a greater volume contains more heat energy than a system of the same liquid and temperature with a smaller volume.

III. Thermal energy is conserved when liquid systems are combined. (Section F)

   a. When two volumes of a liquid at the same temperature are mixed, the temperature of the mix will be the same as that of each of the original samples.

   b. When two equal volumes of a liquid at different temperatures are mixed, the temperature of the mix will be midway between the temperature of the original samples.

   c. When two unequal volumes of a liquid at different temperatures are mixed, the temperature of the mix will fall somewhere between the temperatures of the original samples.

d. When samples of a liquid are mixed, the heat energy of the mix is the sum of the heat energies of the original samples.

e. Heat energy is neither gained nor lost when water samples are mixed.

IV. The heat energy that is absorbed when a substance changes from a solid to a liquid or from a liquid to a gas is released when that change of state is reversed. (Section G)

a. Heat energy is absorbed by a system with no increase in temperature when it does work on the system.

b. The particles of many solids are held together in a regularly shaped pattern by binding forces.

c. The heat energy that is absorbed when a solid changes to a liquid is used to overcome the binding forces between particles (molecules).

d. Heat energy can do the work of overcoming the binding forces that hold particles in a regularly shaped pattern.

e. Binding forces can re-form the particles into a regularly shaped pattern when heat energy is removed.

f. Heat energy is absorbed when a solid changes to a liquid and when a liquid changes to a gas.

g. Heat energy is released when a gas changes to a liquid and when a liquid changes to a solid.

h. A gas has more energy and thus its particles are moving more freely than those of its liquid (at the same temperature).

i. A liquid has more energy and thus its particles are moving more freely than those of its solid (at the same temperature).

V. Work is done when a force moves an object through a distance. (Section H)

a. The amount of work done by a force is the product of the force and the distance moved.

VI. The two forms of mechanical energy, kinetic and potential, can be transformed from one to the other. (Section I)

a. A moving object possesses an amount of kinetic energy that is related to its speed.

b. An object that possesses kinetic energy has the ability to do work.

c. The potential energy of an object increases when work is done to lift the object against a gravitational force.

d. Potential energy is stored in an elastic device when work is done to stretch or compress it.

e. Potential energy can be changed into kinetic energy.

VII. Some solid salts and water interact to form a clear liquid, called a solution. (Section J)

a. When some solid salts form a solution with water, heat energy is absorbed by the solution.

b. An attractive force between water and the particles of some solid salts helps to overcome the binding force between the particles, thus freeing them from each other so as to form a solution.

c. Melting and dissolving are analogous processes in the sense that in each case a mobile liquid is formed from a rigid solid.

d. The mobile particles of a melt or a solution possess more energy and thus move more freely than do the particles in their respective solids at the same temperature.

VIII. The heat energy that is absorbed when a salt dissolves will be liberated when the salt precipitates. (Section K)

a. The particles of a solid salt are held together in a regularly shaped pattern by binding forces.

b. When some solid salts form a solution with water, heat energy is absorbed by the solution.

c. Heat energy is released from the solution when the particles of a dissolved salt precipitate.

d. The heat energy that is absorbed when salt particles go into solution is added to the energy of the particles in the solution.

e. A supersaturated salt solution contains more dissolved particles and heat energy than the same volume of a saturated solution of the same salt (at the same temperature).

f. The heat energy that is released when the mobile particles of a salt in solution precipitate comes from the energy of the particles.

g. The heat energy that is absorbed when the temperature of a system increases is released when that system returns to its original condition.

IX. The heat energy that is used to break the bonds that hold water particles in a hydrated salt is released when the bonds re-form. (Section L)

a. The heat energy that is absorbed by an apparently dry salt may drive off water that is bonded to the salt.

b. The bonds between water particles and the salt particles in a crystalline structure may be broken when heat energy is absorbed.

c. Heat energy is released when bonds are formed between water and salt particles.

X. The total amount of energy in a system remains constant. (Section M)

a. The amount of work done to increase the gravitational potential energy of an object does not depend on the path through which the object is lifted.

b. In an ideal system, the different forms of mechanical energy can be converted from one to the other without any loss of mechanical energy.

c. The kinetic energy of an object can be transformed into thermal energy.

d. A loss in the mechanical energy of a system may be accounted for by the production of heat energy due to frictional forces.

Split-half Categorization of the Critical-Terms Test Items

HALF: I		HALF: II	
Item	Critical-term	Item	Critical-term
2	(to) melt	1	(a) model
3	greater than	4	speed
5	amount of stretch	6	(a) solid state
7	(more) measures	9	equal
8	balanced	10	kinetic energy
12	unequal	11	unbalanced
13	change of state	14	(more) distance
17	(a) graph	15	less than
18	heat energy	16	an opposing force
20	(a) thermometer	19	liquefy
22	binding force	21	(an) attractive force
25	(a) liquid state	23	(a) crystal
26	evaporate	24	(a) force
28	potential energy	27	solidify
29	(a) particle	30	horizontal
32	vertical	31	work
A	dissolve	B	gravitational field
C	predict	D	energy
E	unit	F	temperature
I	weight	G	(to) graph
J	(a) mix	H	(a) melt
L	(a) gaseous state	K	(a) solution
M	friction	N	(a) heat energy unit

APPENDIX C

SPECIAL EQUIPMENT

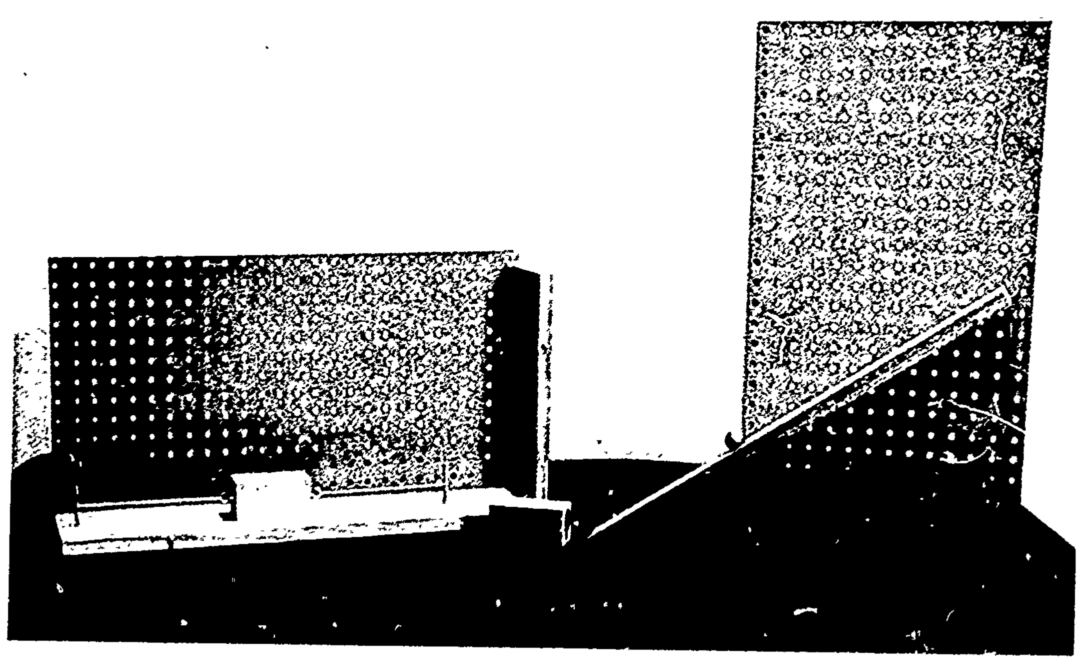
FOR THE

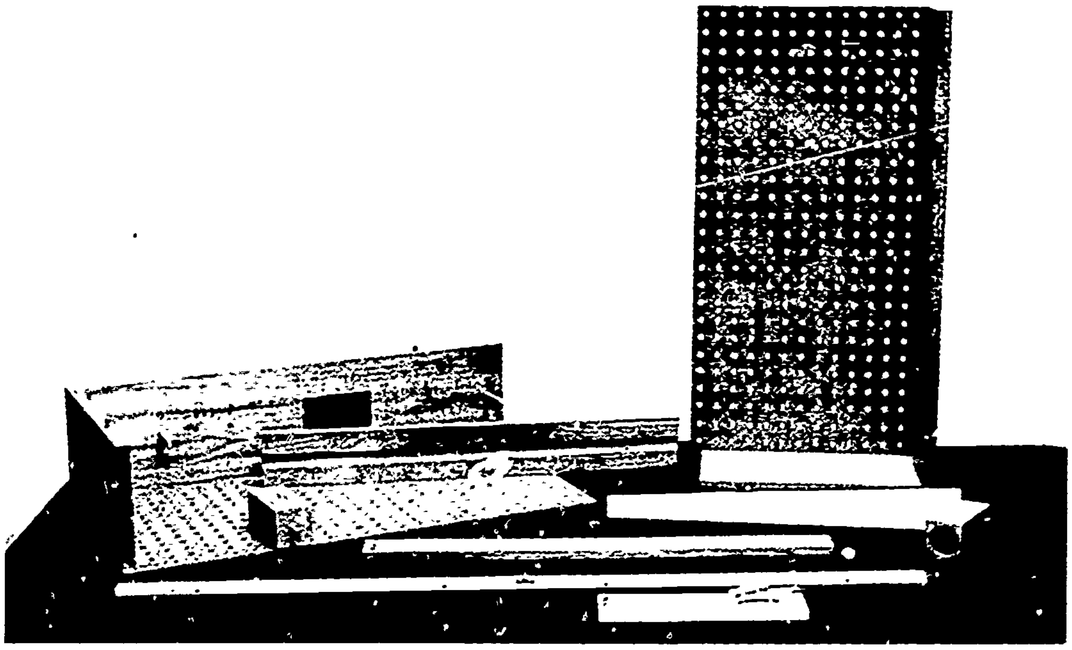
CONSERVATION OF ENERGY SEQUENCE

THE DEVELOPMENT OF SPECIAL EQUIPMENT

In developing the learning activities for the COPES pilot study, careful attention was given to the nature of the materials and equipment required to perform the activities. It was decided that the materials and equipment to be used should meet several criteria. They should be readily available, low in cost, safe to operate, rugged, manageable by elementary school children, and easily stored. Commerically produced materials and equipment meeting these criteria were available for all activities in the thermal energy segment. This was not the case for all materials and equipment in the mechanical energy segment, although a few items such as the inclined plane and pendulum were available.

Since most of the COPES activities involve pupil participation, either individually or in pairs, many pieces of equipment were required. Thus, the criteria of cost and storage could not be met by standard commercial materials for the mechanical energy segment. It was, therefore, considered necessary to construct certain items of equipment and to design a package for them. The package consisted of a compact, portable box unit (26" x 14" x 6"). Thirty such units were constructed for use with the classes in the Great Neck teaching program.





The box contained equipment and materials which, when assembled, provided the needed set-ups for all the activities in Sections D, I, and M of the main sequence. The two large sides of the box were constructed from peg-board and served as panels for mounting pieces of equipment in various positions. The smaller sides, constructed from hardwood, provided a base for the peg-board panels. The hardwood sides also served as supports for equipment used in particular activities, such as balanced forces and gravitational force (weight). The illustration on page C-1 shows some of the ways by which sides of the box were used to mount equipment. The two halves of the peg-board box, as shown in the illustration above, were made to fit together to form a compact carrying case. Each complete package was designed to serve four children working in pairs. Detailed specifications of all materials contained in the package and ways in which they are to be used are presented in The Teacher's Guide.

Although the equipment package served its intended purposes, the pilot test brought out some minor inadequacies in design, which should be corrected before the unit is released for general use.

APPENDIX D

SAMPLE REACTION SHEETS

USED BY TEACHERS

TEACHER'S REACTIONS TO COPES GUIDE FOR

PRESEQUENCE TEACHING MATERIALS

(Conservation of Energy)

Please check the appropriate section and indicate the activity by number (for example, IA1) to which you are reacting.

School_______________

Teacher_______________

Grade_______________

______I. Time, Space and Motion

_____II. Pushes and Pulls

____III. Matter and Heat

Activity Number _______

Please indicate below suggestions you may have for clarifying the materials needed and the description-of-activity portions of the Activity both before and after observation of the teaching of the activity. Suggestions made after observing the teaching might include those which will improve future experience with this material. Please indicate on the back of this page any additional experiences which might be used to implement this activity.

Portion of Activity	Before Observation	After Observation
Materials needed		
Suggestions for Teaching		

(Please use the back of this page for a continuation of this section and for suggesting additional experiences.)

TEACHER'S REACTION TO COPES GUIDE FOR
THE CONSERVATION OF ENERGY SEQUENCE

Major Concept (please write out major concept as it appears in the Guide)

____

____

____

School ______________

Teacher ______________

Grade ______________

Activity Number ____________

Please note your reactions in the spaces below to the activity as it appears in the Guide. It is hoped that you include in your reactions (1) points that are not clear to you, (2) whether or not it is clear why the activity is placed as it is in the sequence of activities designed to develop this major concept, and (3) points about which you need background information.

Portion of Activity	Before Observation	After Observation
Materials		
Suggestions for Teaching		

(Please continue on the back if necessary)

TEACHER'S REACTION TO COPES GUIDE FOR
THE CONSERVATION OF ENERGY SEQUENCE

Major Concept (Please write out major concept as it appears in the Guide)

School________________

Teacher_______________

Grade________________

Please indicate your reactions to the introductory material to the major concept <u>only</u>. (You will be asked to react to each activity related to each of the major concepts on other sheets.) It is hoped that you will include in your reactions (1) points that are not clear to you, (2) whether or not this section makes clear why this concept is placed as it is in the entire sequence, and (3) points about which you need background information.

1. Reactions before observations of teaching toward this concept.

2. Reactions after observations of teaching toward this concept.

(Please use the back of this sheet if you wish.)

APPENDIX E

DEVELOPMENT OF THE COPES TESTS

COPES Test of Critical Terms

COPES Test of Science Concepts, Section 1

COPES Test of Science Concepts, Section 2

COPES Test of Science Concepts, Section 3

DEVELOPMENT OF THE COPES TEST

Two types of concepts were identified in designing the sequence and in preparing the teaching materials. One of these types is represented by a single word or, in some case, two words with one meaning, such as kinetic energy. These concepts are considered critical to an understanding of the conservation of energy, and hence, are referred to as critical terms. The second type of concept is represented by a statement that indicates a relationship among the more basic ocncepts and that is relevant to the conservation of energy. For brevity, these concepts are referred to as major concepts and supporting concepts. A test was prepared to assess children's understandings of each of these types of concepts. The means by which the tests were developed are described below.

The COPES Test of Critical Terms

The initial step in the development of the COPES Test of Critical Terms was to analyze all teaching materials and transcripts of lessons taught at the time the materials were being tried out with children in the laboratory school. Whenever there appeared a word or a phrase that might represent a basic concept in the sequence, the term was listed. More than 130 such terms were thus identified.

These 130 terms were then evaluated by a panel made up of a scientist, a psychologist, and three science educators, one of whom was an evaluation specialist in elementary education. The criterion applied by the panel was: Does this term represent a concept that is critical in understanding one or more of the ten major concepts? In the panel's judgment, approximately one-fourth of the proposed terms satisfied this criterion. A test item was then prepared for each of forty-six critical terms. The majority of these items were multiple choice picture items and the others were multiple choice word items. The items were submitted to the panel and then revised in light of its criticism.

The tests were administered on a try-out basis to kindergarten, second grade, fourth grade, and sixth grade children in one of the project's cooperating schools. Based upon the results, the relative difficulty of each item was determined, and the items were arranged in ascending order of difficulty in the final test.

The COPES Test of Science Concepts

The conservation of energy sequence was designed around ten major concepts. Each of these was analyzed to identify subordinate, or supporting, concepts. Because of time limitations in test administration, it was decided to construct a test to assess children's understandings of each of the ten major concepts. It was assumed that children who understand a major concept will have a reasonably good understanding of the concepts that are subordinate to, and supportive of, it.

It was decided to use Suchman's* PCE model for this test. This was done by setting a problem situation to which one of the major concepts was applicable. In taking the test, the examinee is required to select from several statements a prediction having to do with the problem (P) situation, to select from another list of statements what he would do to control some action in the problem situation (C), and to select from a final list of statements the one that best explains why he made the prediction and why he chose the control he did (E).

Ten such test problems were constructed, each one corresponding to one of the ten major concepts. A situation was chosen for each problem that children could be expected to understand on the basis of their experience but that is not dealt with in the teaching activities of the sequence. In preparing the statement choices for the test items, more than one correct statement was frequently used. Thus, in selecting a statement that represents the best choice to answer the test item, an examinee is required to decide the relevance, as well as the correctness, of the statement. Attention was given to the suitability of vocabulary for elementary school children, and an effort was made to avoid giving clues to best statements. For example, if the best choice were a long sentence, an equally long distractor was included; in cases where a science word might offer a clue, that word was also used in a distractor.

As each test problem was first proposed, it was critically examined by the same panel that examined the test items for the COPES Test of Critical Terms. Tape recordings were made of the panel's discussion and its decisions on each item in the test.

The test problem was then revised and submitted for reexamination by the panel. By this process, each test problem went through a number of revisions. Once it finally passed the panel, it was tried out with children in the COPES laboratory school to determine where it failed to communicate with them. Based upon evidence obtained from children, it was again revised. Finally, each test problem was checked by another scientist. It is estimated that about twenty man-hours were required to produce each of the ten test problems. Although this test-making process was time-consuming, it was generally agreed that the product was worth the effort.

The test of ten problems consisted of thirty test items. The printed test was then prepared in three sections so they could be administered separately in time periods that are reasonable. Sections 1 and 2 each consisted of twelve test items dealing with four problems, and Section 3 had six items relating to two problems.

Samples of both the COPES Test of Critical Terms and the three sections of the COPES Test of Science Concepts are included in the following section of this appendix.

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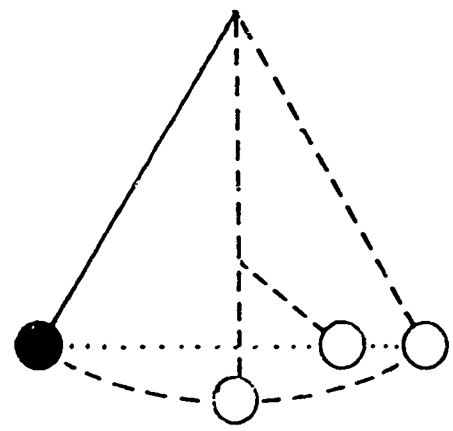
*Richard J. Suchman, The Elementary Science Training Program in Scientific Inquiry, University of Illinois, 1961. U. S. Office of Education, Project No. 216.

COPES



Test of Critical Terms

An Experimental Test
to
Measure Understandings of Critical Terms
Used in the
Conservation of Energy Sequence

Your Name ______________________________

Boy or Girl ______________ Your Grade ______________

Your School ______________________________

Your Teacher's Name ______________________________

Today's Date ______________________________

DO NOT OPEN THE TEST BOOKLET UNTIL YOU ARE TOLD TO DO SO.

COPES PILOT TEST

PRELIMINARY DRAFT

SUBJECT TO FURTHER REVISION.

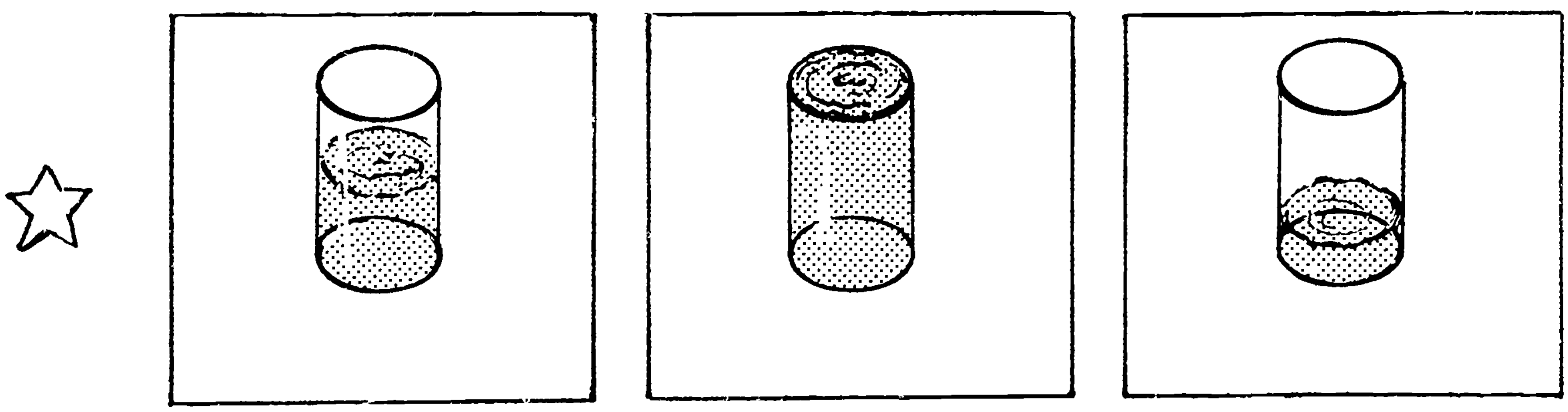
APRIL 1967

PART 1

You will be asked to show your understanding of some science words by marking pictures to show the best meanings of the words. The first science word is a sample word. Try it. Then we will discuss it before you go on.

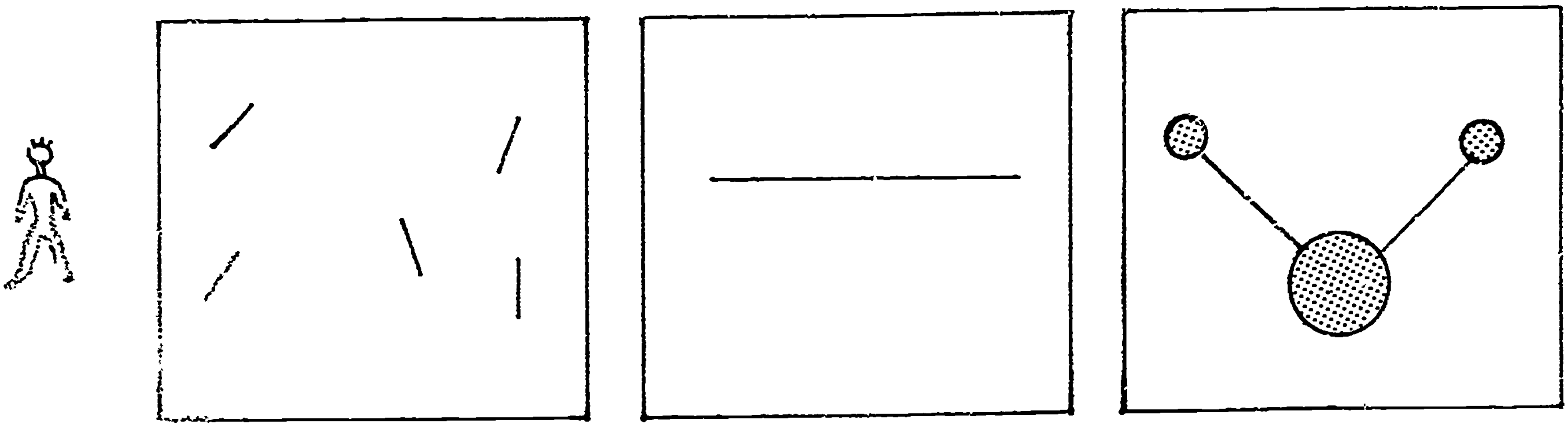
SAMPLE

Direction: One of these three pictures shows a jar with a greater amount of water than is in either of the other two jars. Put an X on that picture.

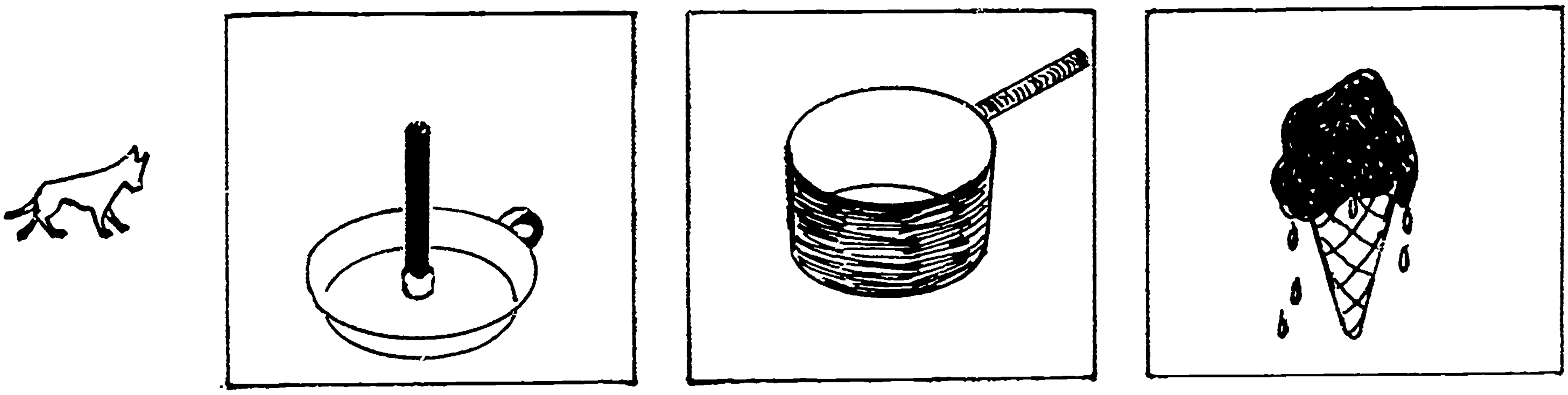


Did you put an X on the middle jar? If so, you were right. Now go on to the other pictures.

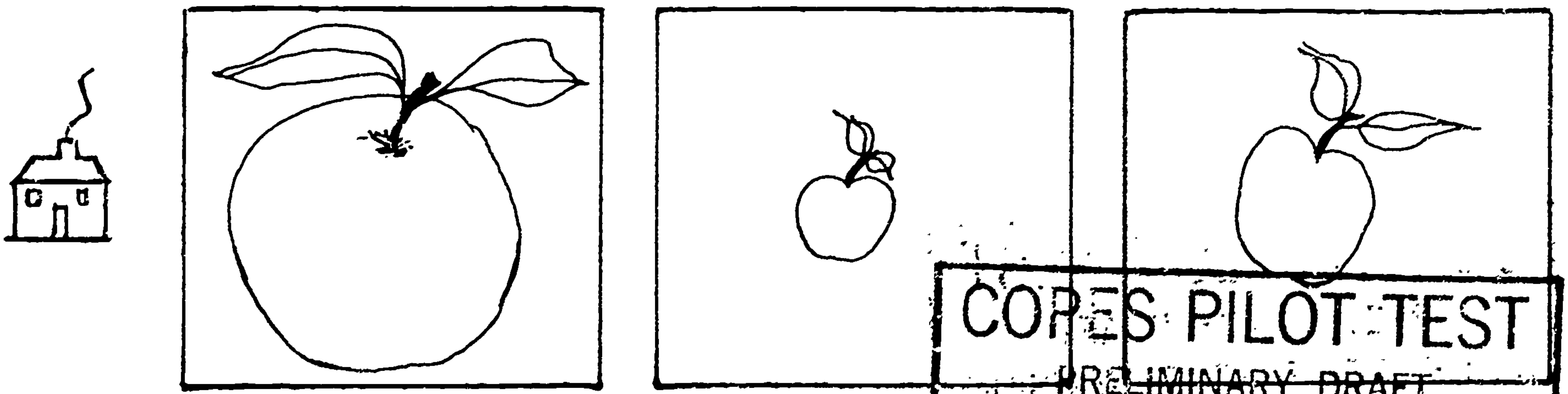
1. Direction: One of these three pictures shows a model of something. Put an X on that picture.



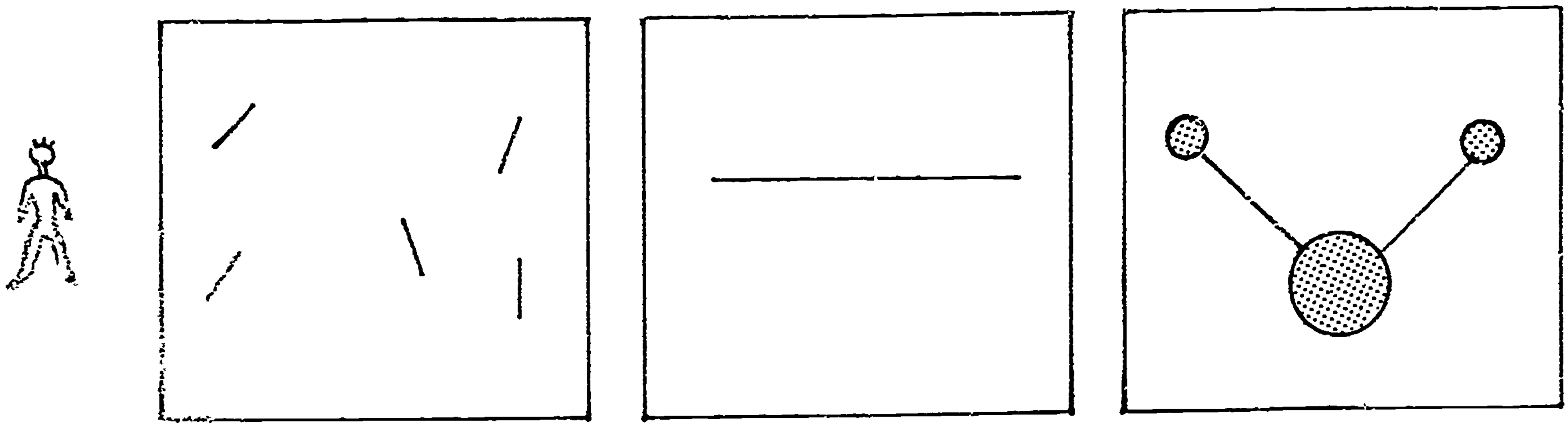
2. Direction: One of these three pictures shows something that is being made to melt. Put an X on that picture.



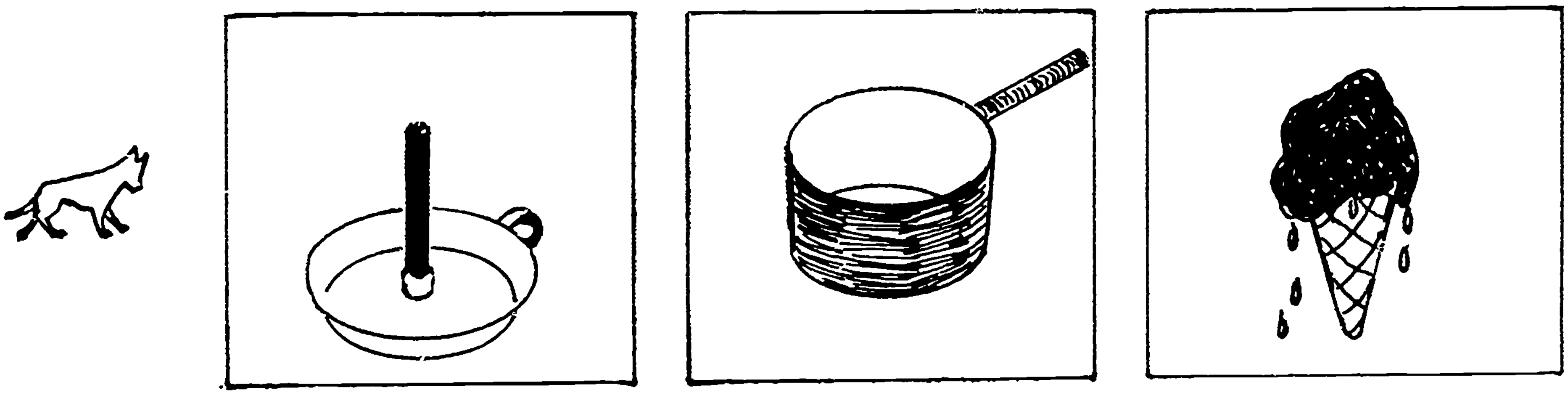
3. Direction: One of these three pictures shows an apple whose size is greater than the sizes of the apples in the other two pictures. Put an X on that picture.



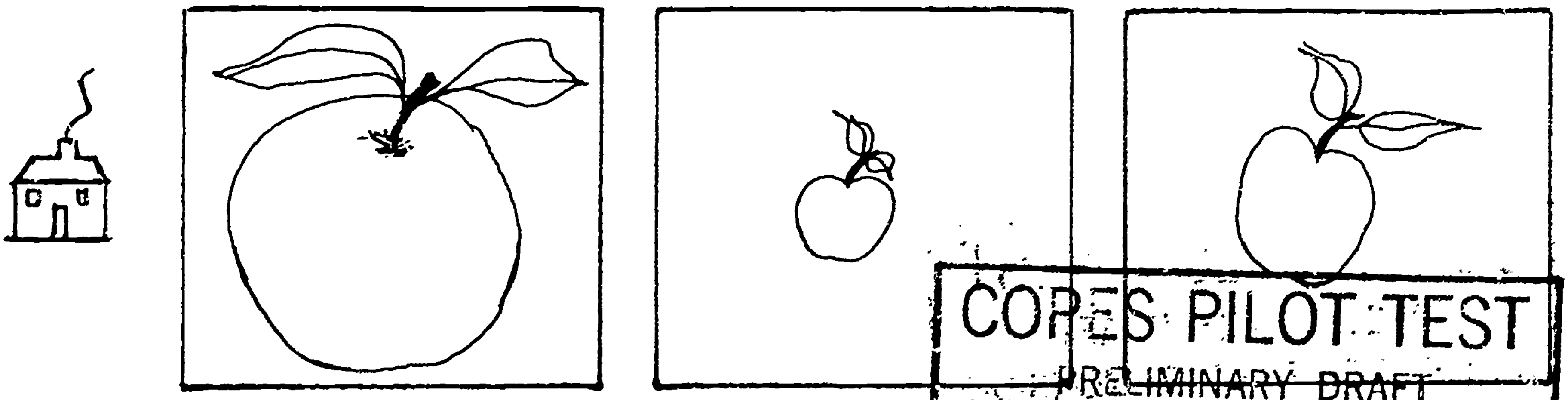
1. Direction: One of these three pictures shows a model of something. Put an X on that picture.



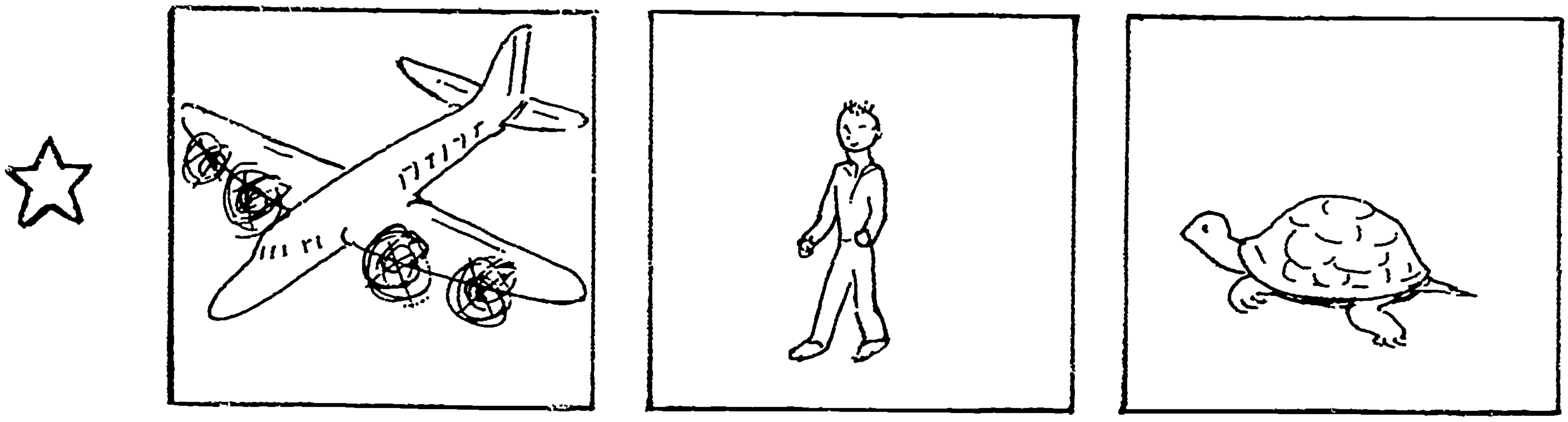
2. Direction: One of these three pictures shows something that is being made to melt. Put an X on that picture.



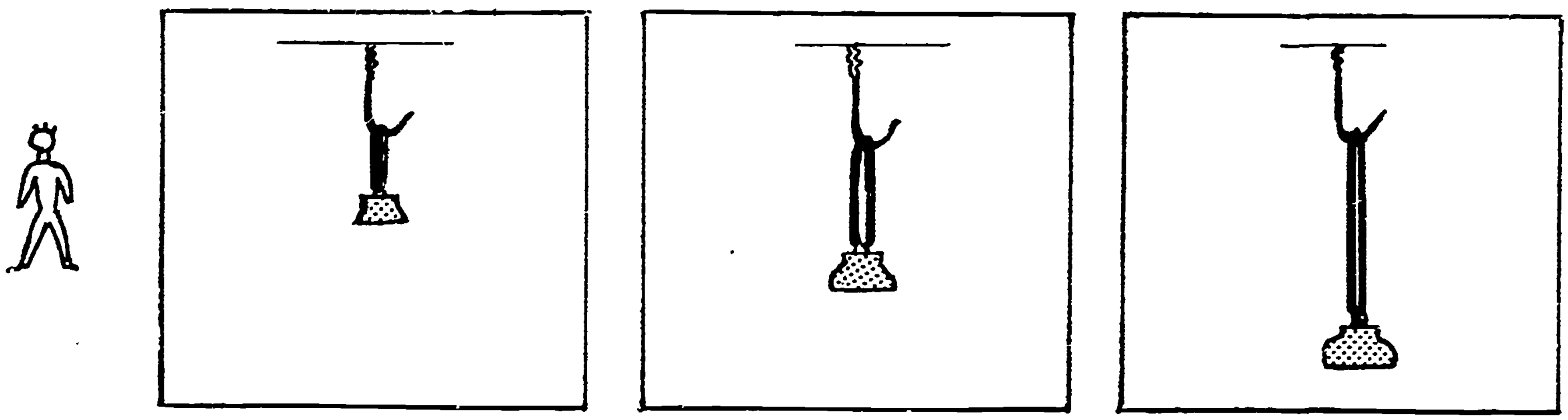
3. Direction: One of these three pictures shows an apple whose size is greater than the sizes of the apples in the other two pictures. Put an X on that picture.



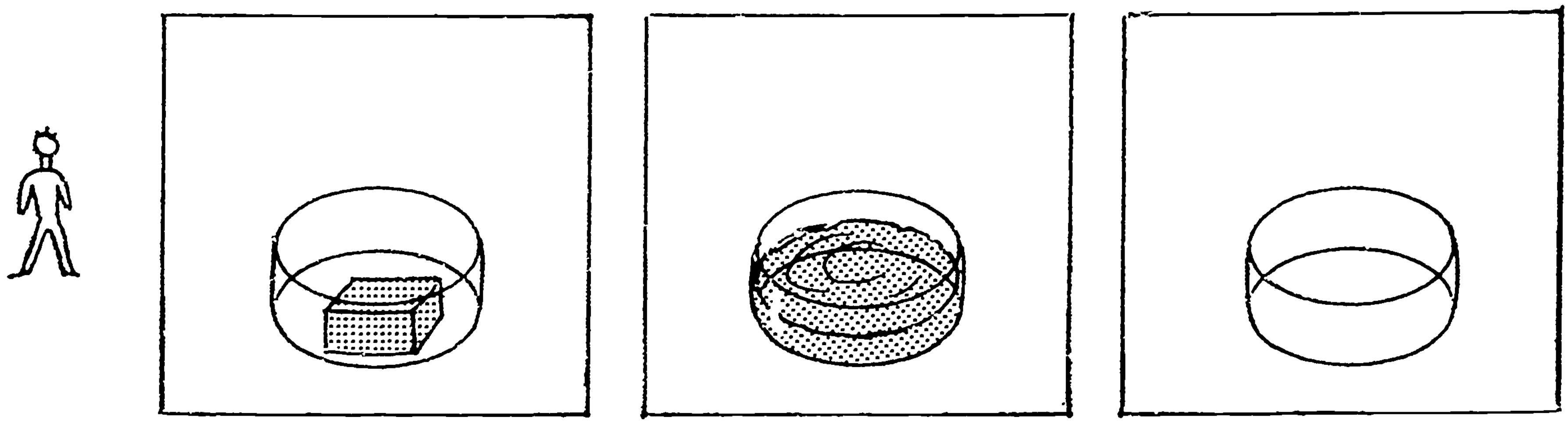
4. Direction: One of these three pictures shows something that can move at a greater speed than the things in the other two pictures. Put an X on that picture.



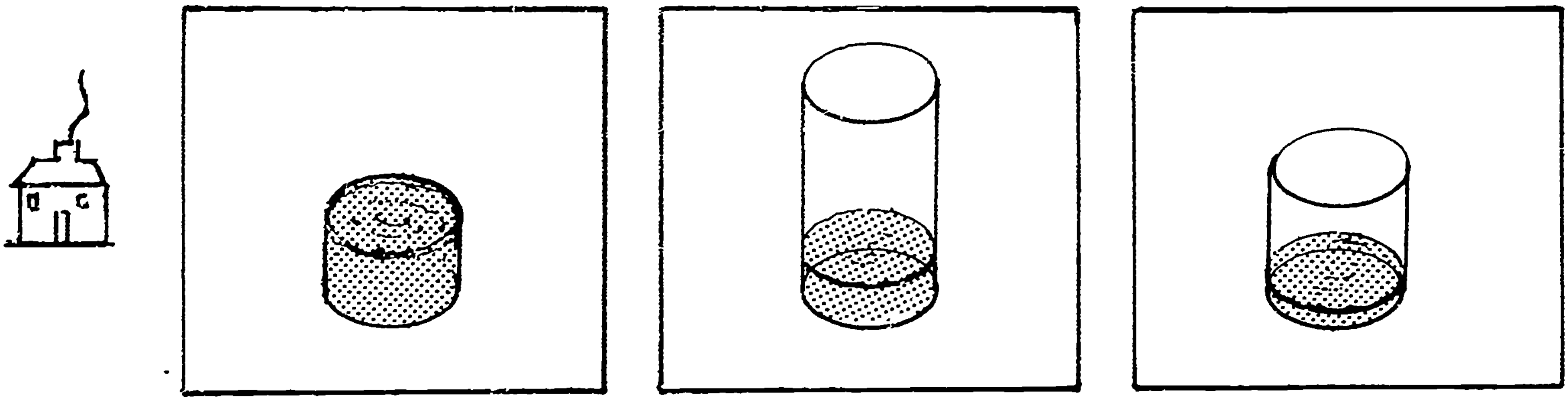
5. Direction: One of these three pictures shows that the amount of stretch on a rubber band is more than it is in the other two pictures. Put an X on that picture.



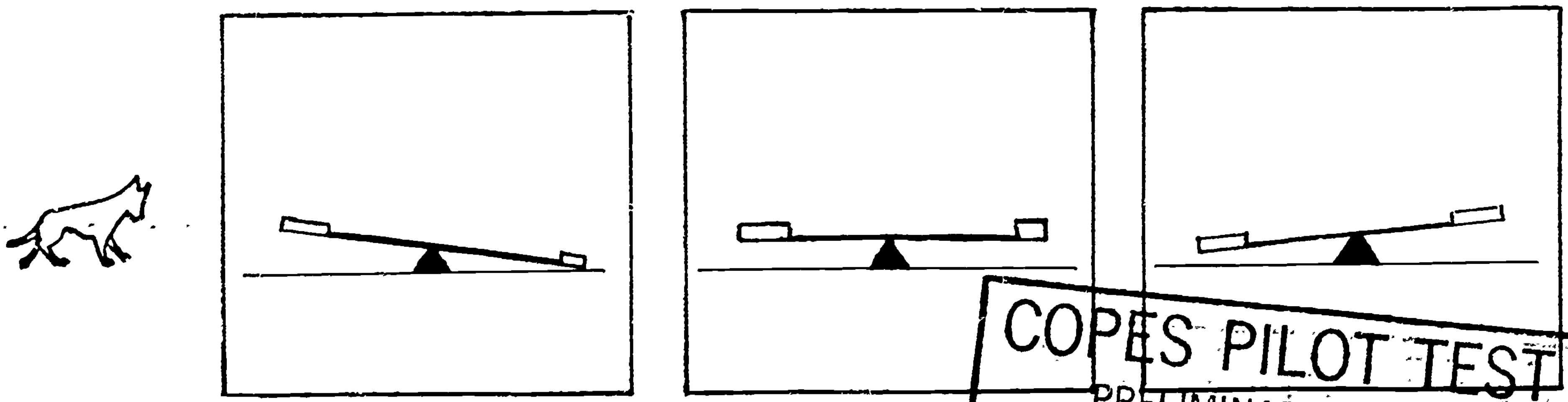
6. Direction: In one of these three pictures, a dish contains something in a solid state. Put an X on that picture.



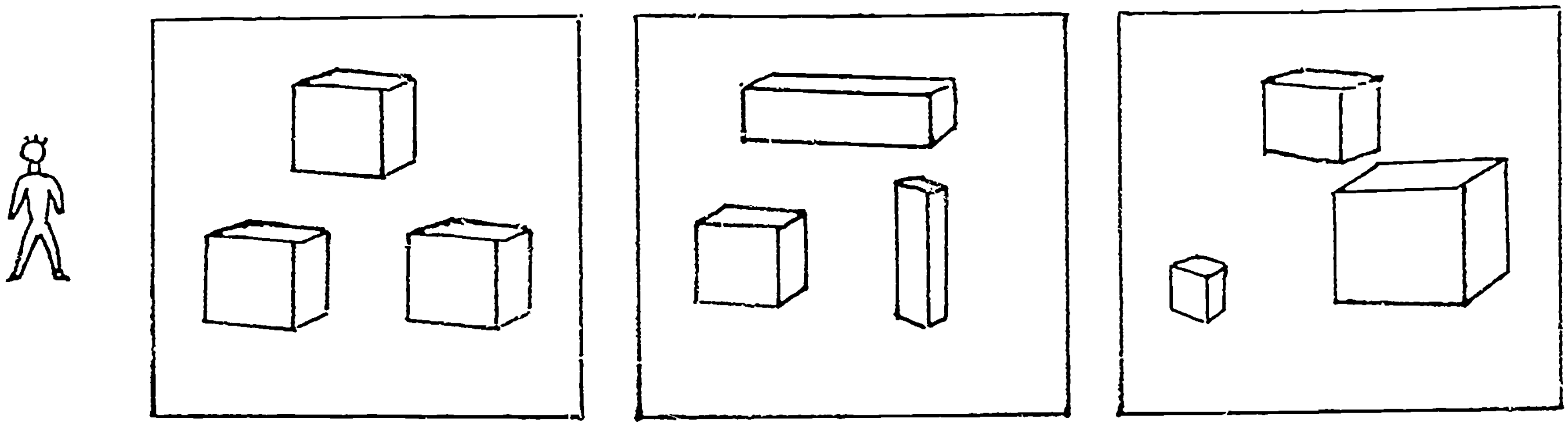
7. Direction: One of these three pictures shows a jar which has more measures of water than either of the other two jars. Put an X on that picture.



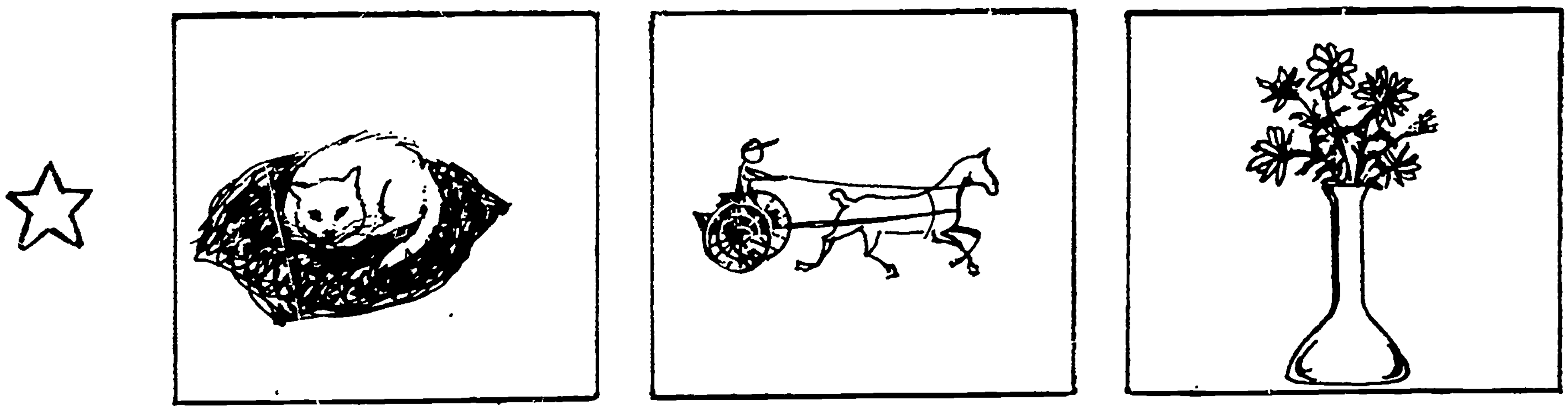
8. Direction: One of these three pictures shows a seesaw that is balanced. Put an X on that picture.



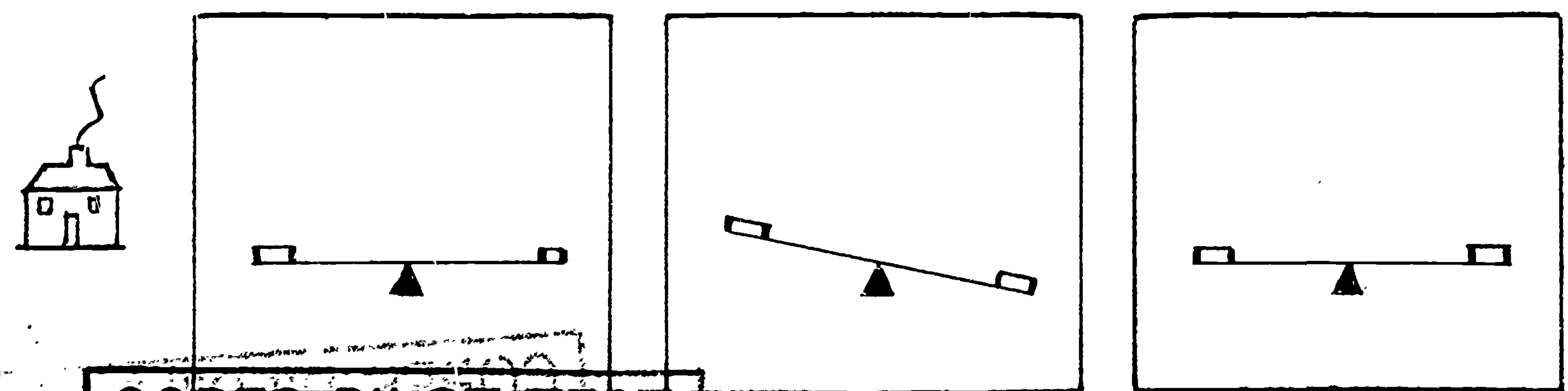
9. Direction: One of these three pictures shows three boxes that are equal in size. Put an X on that picture.



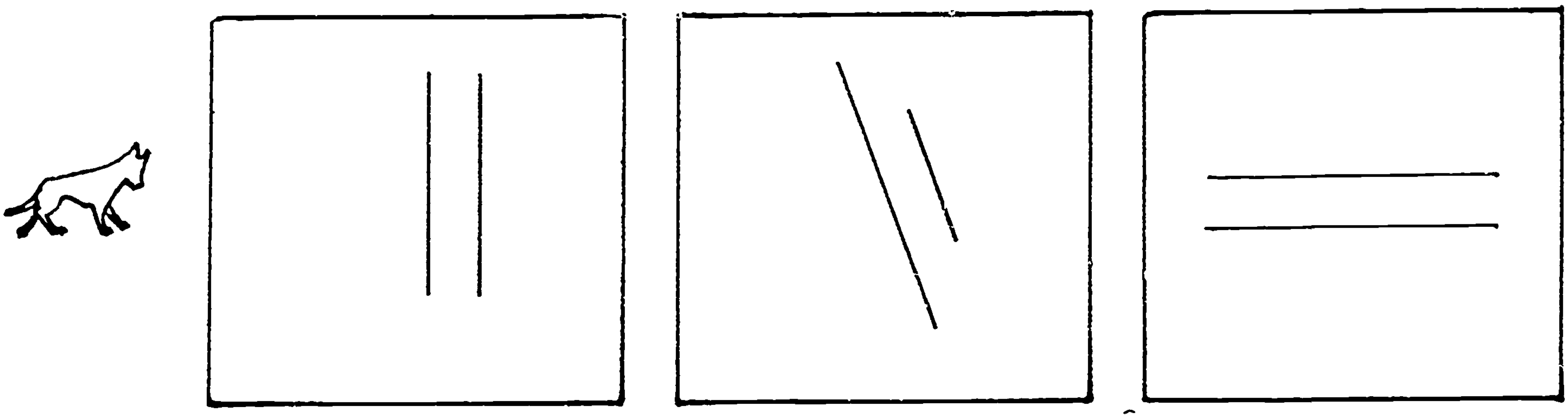
10. Direction: One of these three pictures is about something that has kinetic energy. Put an X on that picture.



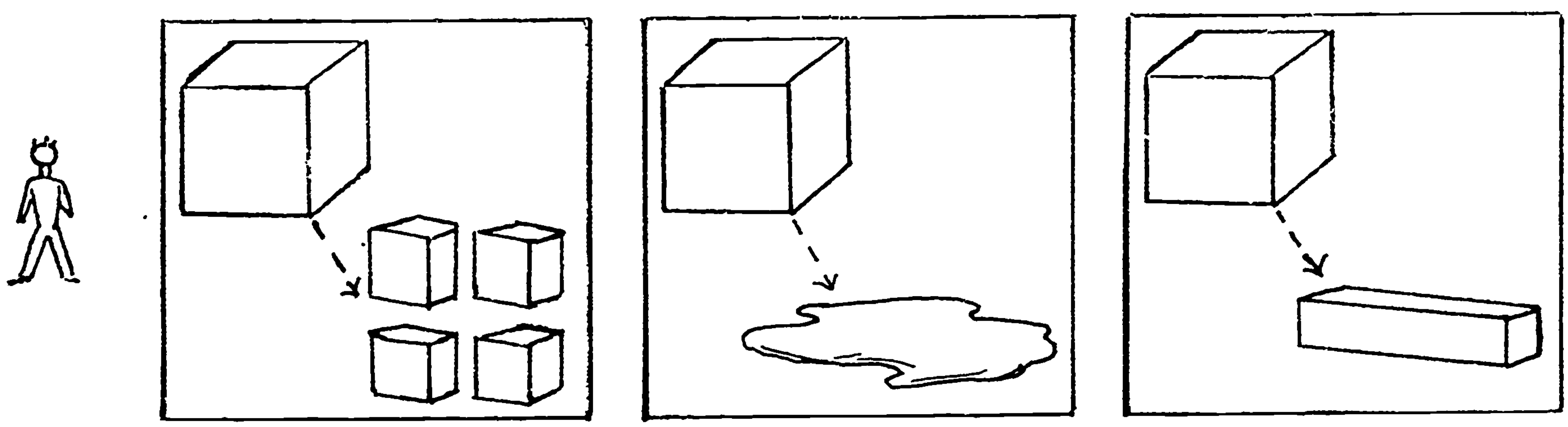
11. Direction: One of these three pictures shows a seesaw that is unbalanced. Put an X on that picture.



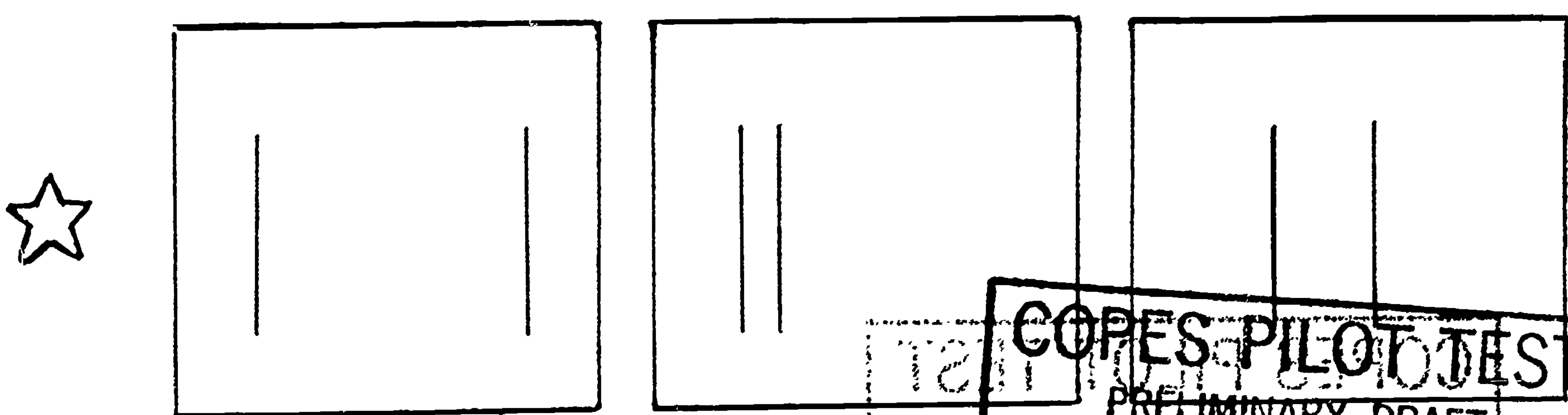
12. Direction: One of these three pictures shows two lines of unequal length. Put an X on that picture.



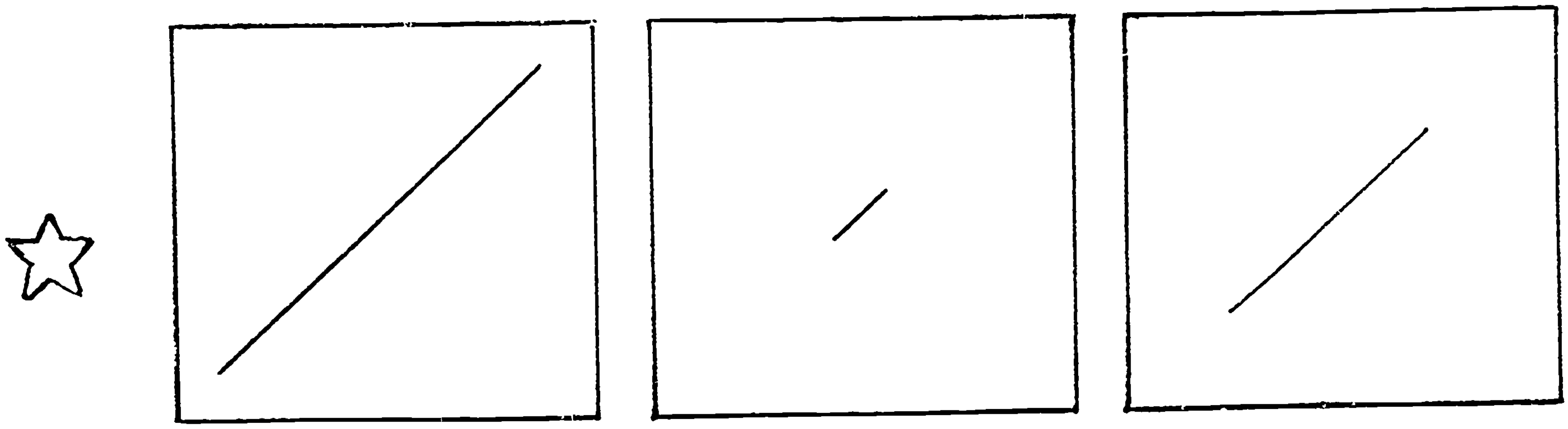
13. Direction: One of these three pictures shows a change of state. Put an X on that picture.



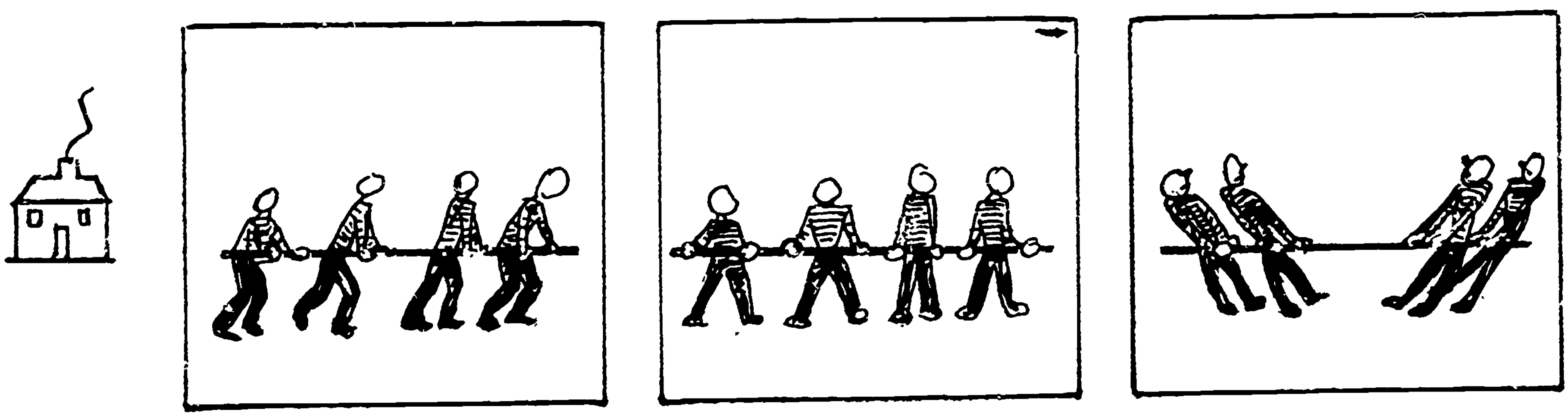
14. Direction: One of these three pictures shows more distance between two lines than is shown in the other two pictures. Put an X on that picture.



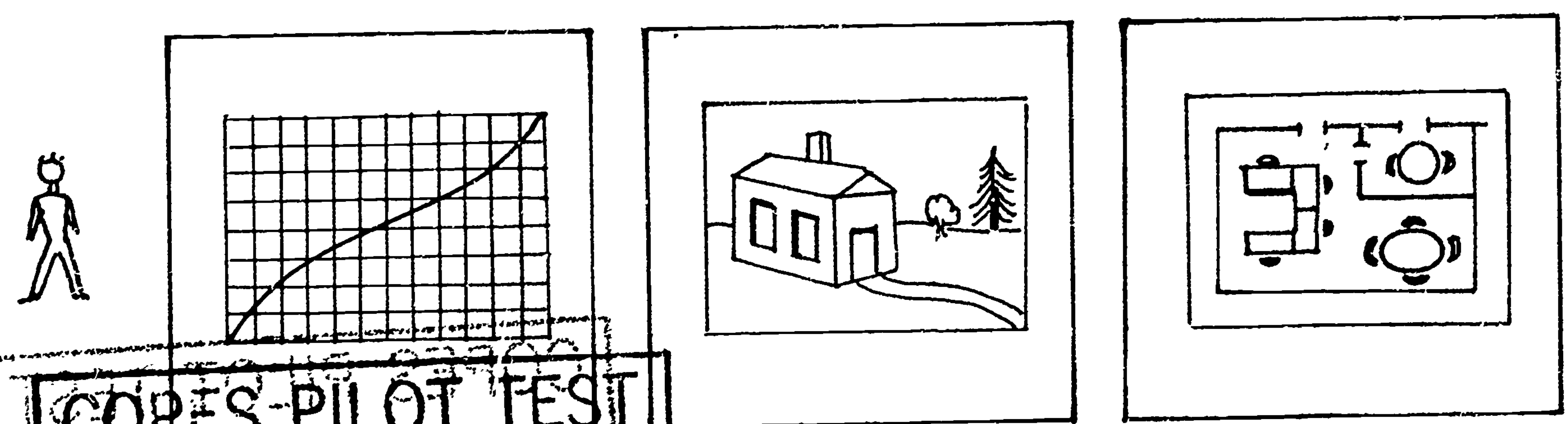
15. Direction: One of these three pictures shows a line whose length is less than the line in either of the other two pictures. Put an X on that picture.



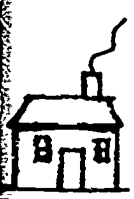
16. Direction: One of these three pictures is about an opposing force. Put an X on that picture.

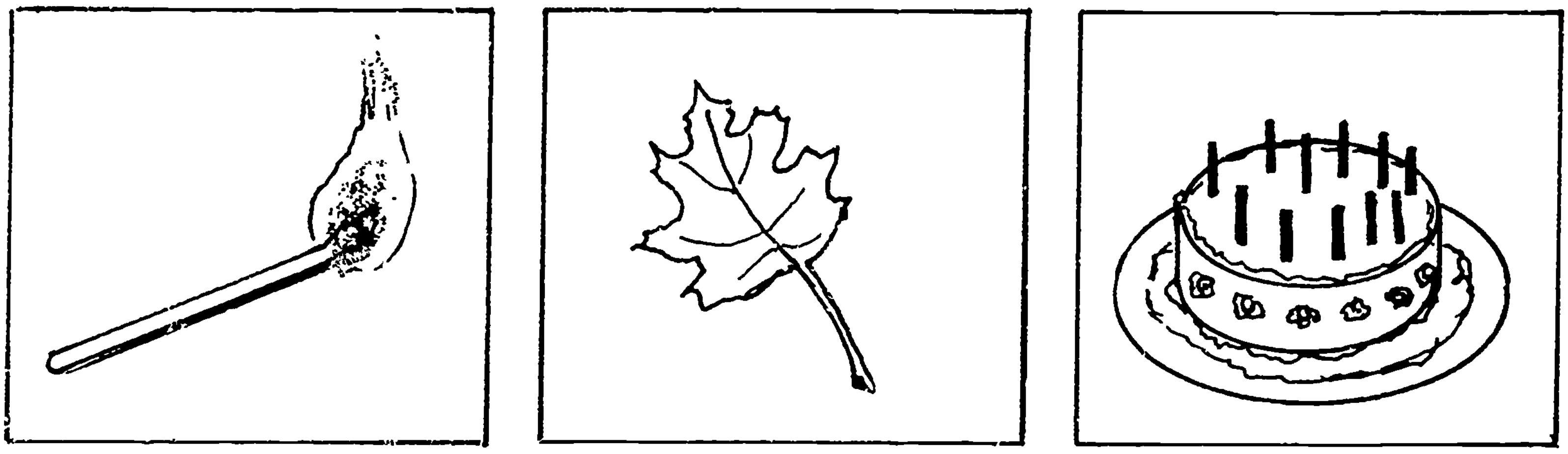


17. Direction: One of these three pictures is a graph. Put an X on that picture.

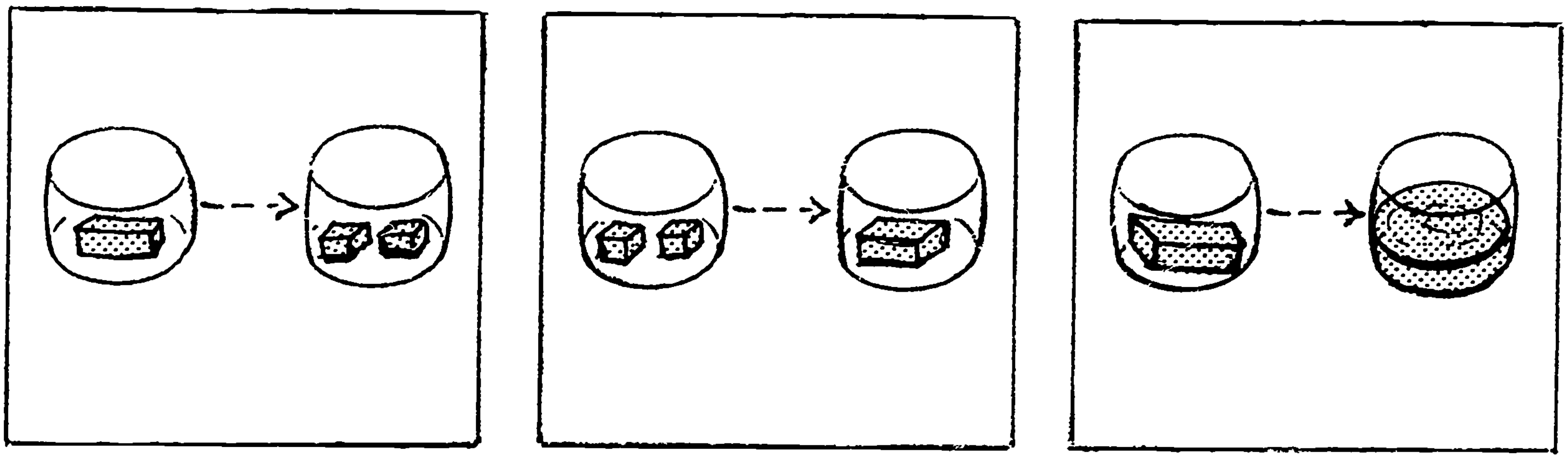


18. Direction: One of these three pictures shows something giving off heat energy. Put an X on that picture.

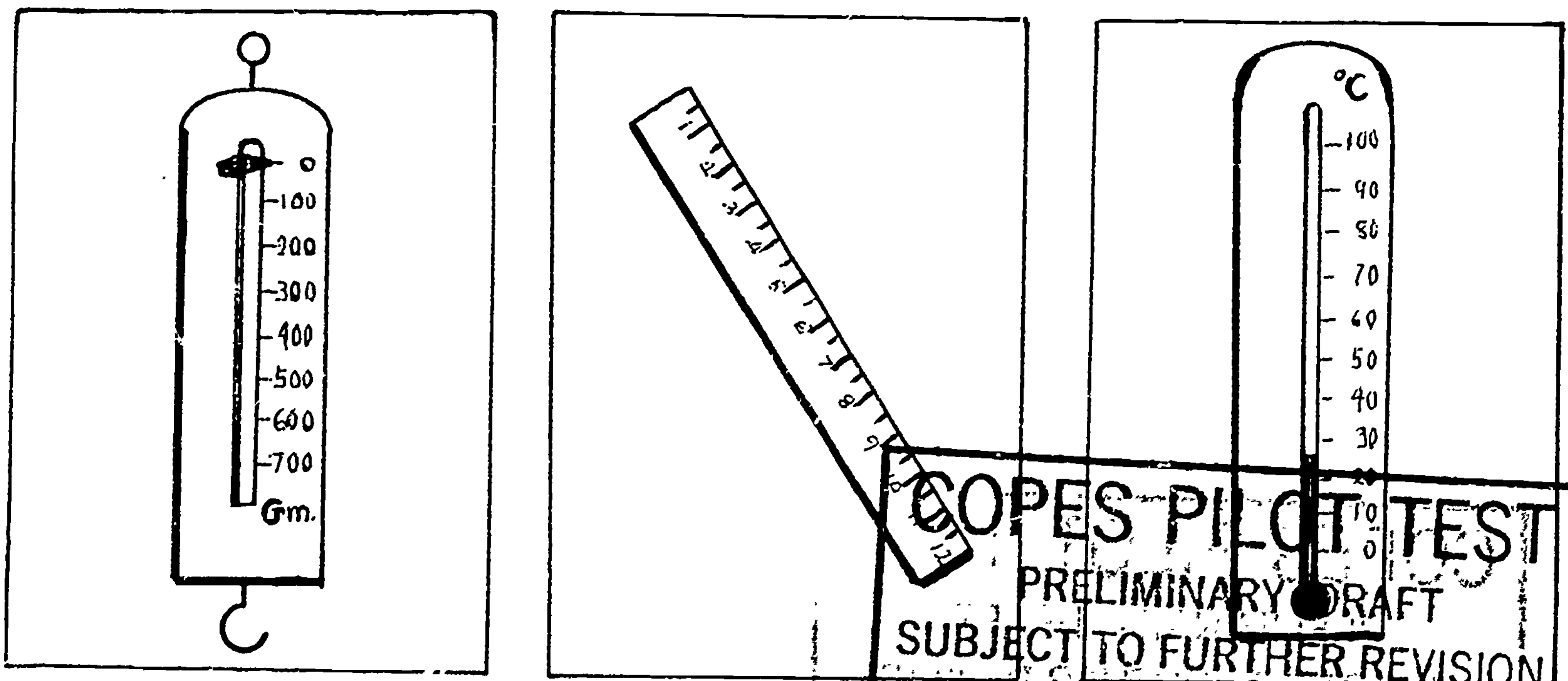




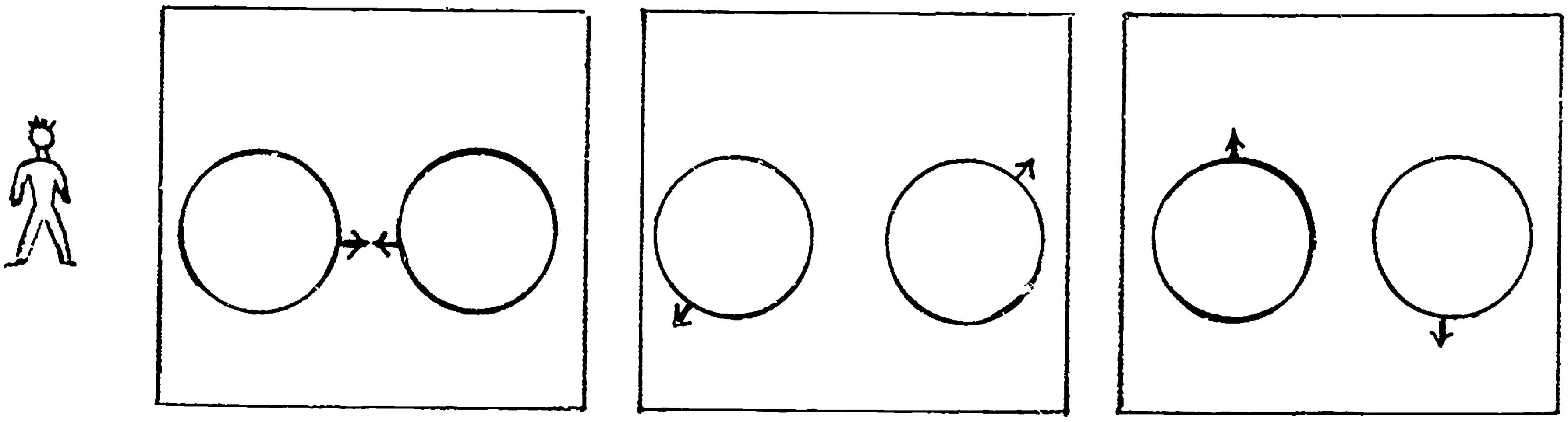
19. Direction: One of these three pictures shows that something can liquefy. Put an X on that picture.



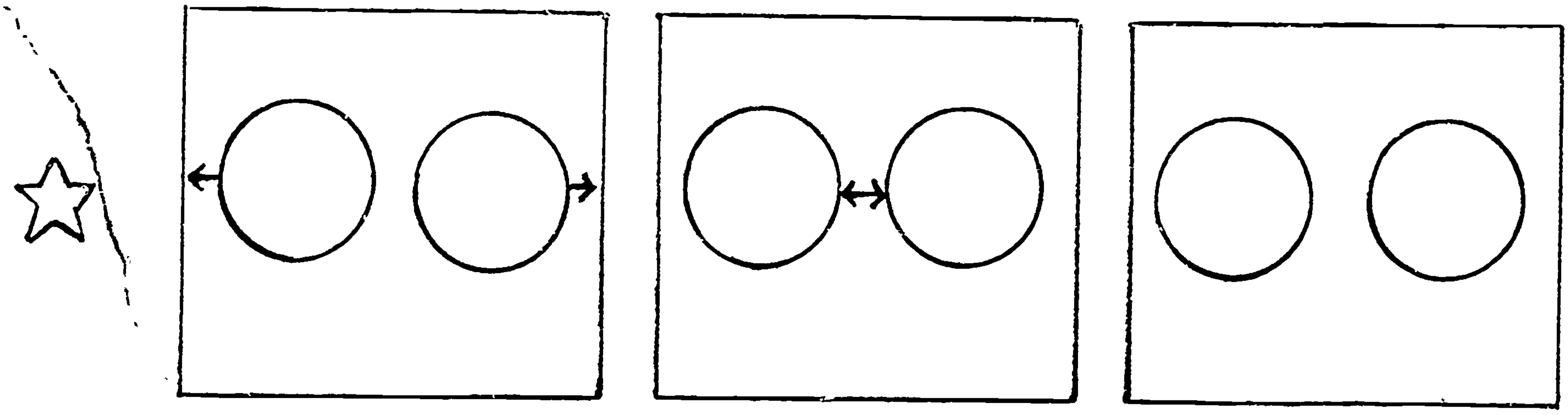
20. Direction: One of these three pictures shows a thermometer. Put an X on that picture.



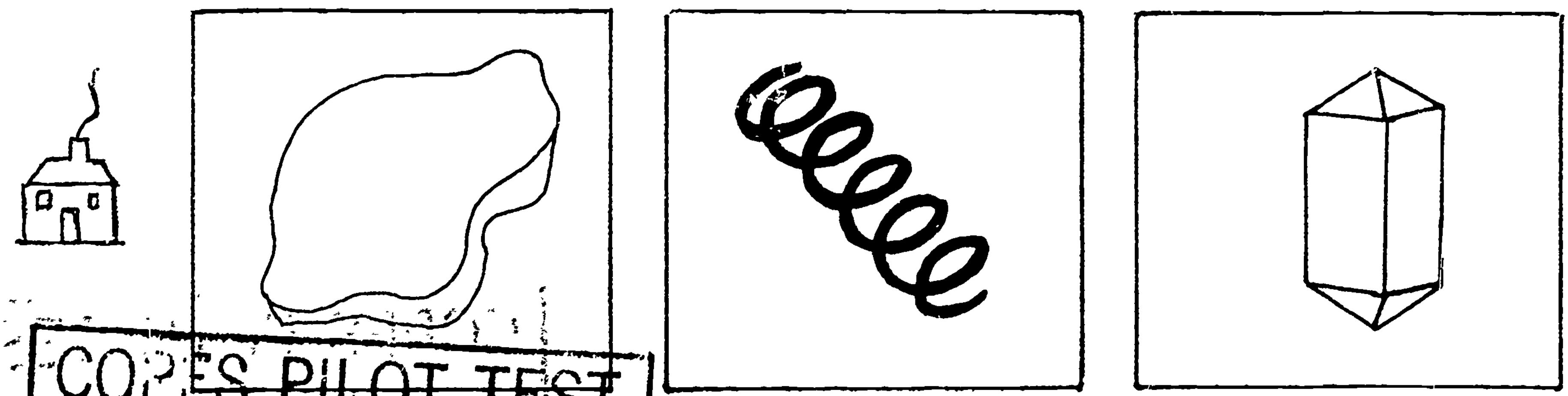
21. Direction: One of these three pictures is about an attractive force. Put an X on that picture.



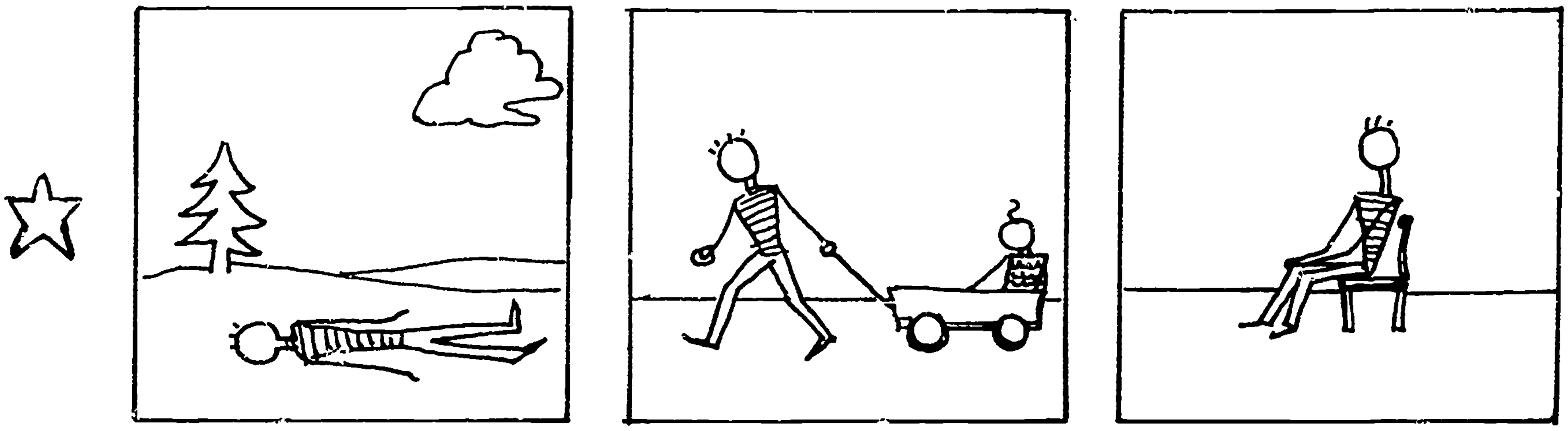
22. Direction: One of these three pictures is about a binding force. Put an X on that picture.



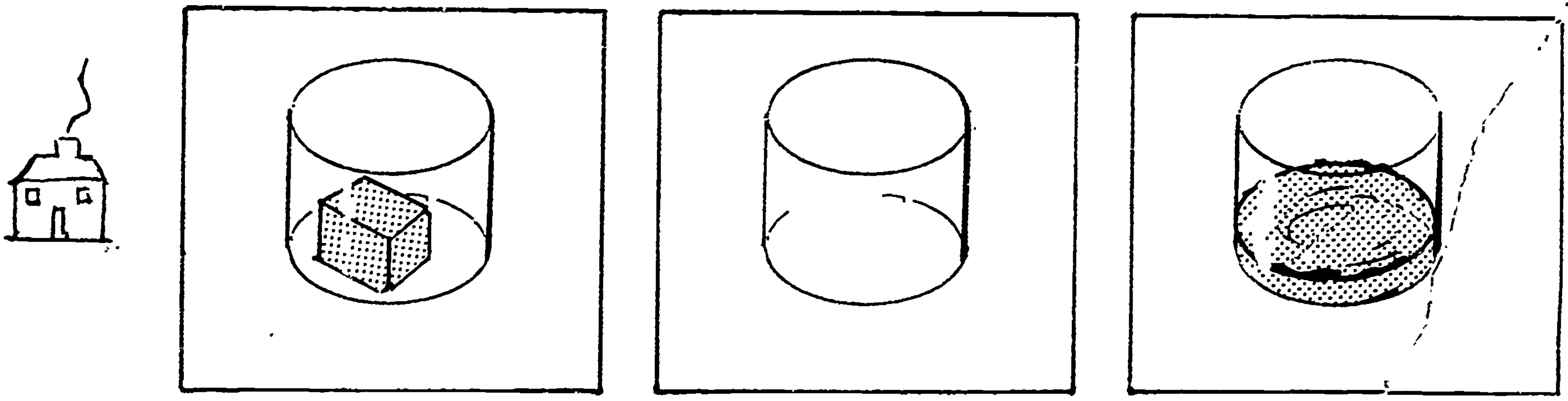
23. Direction: One of these three pictures shows a crystal. Put an X on that picture.



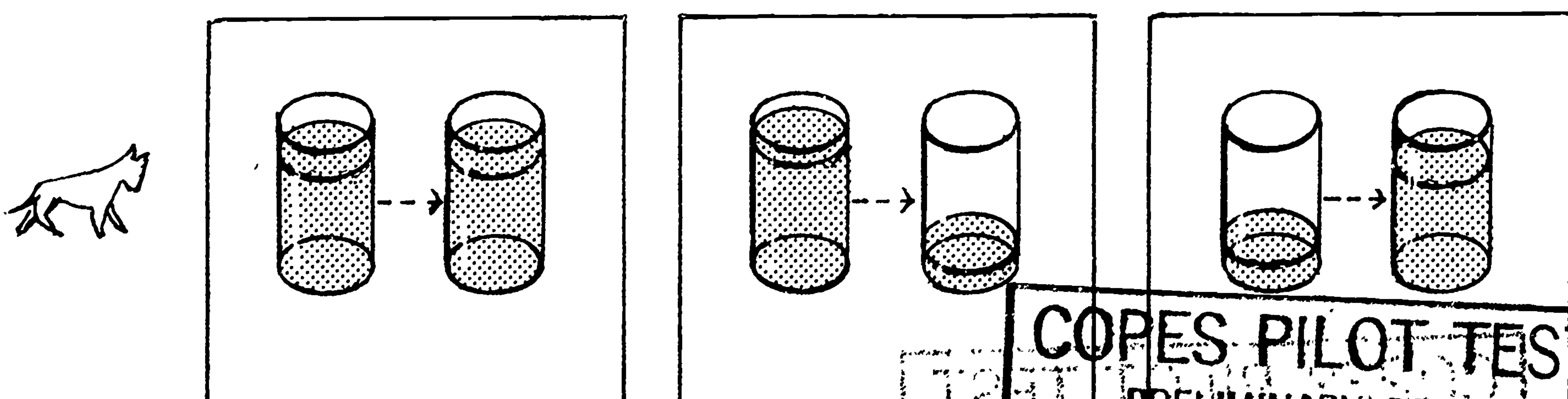
24. Direction: One of these three pictures shows a boy using a force. Put an X on that picture.



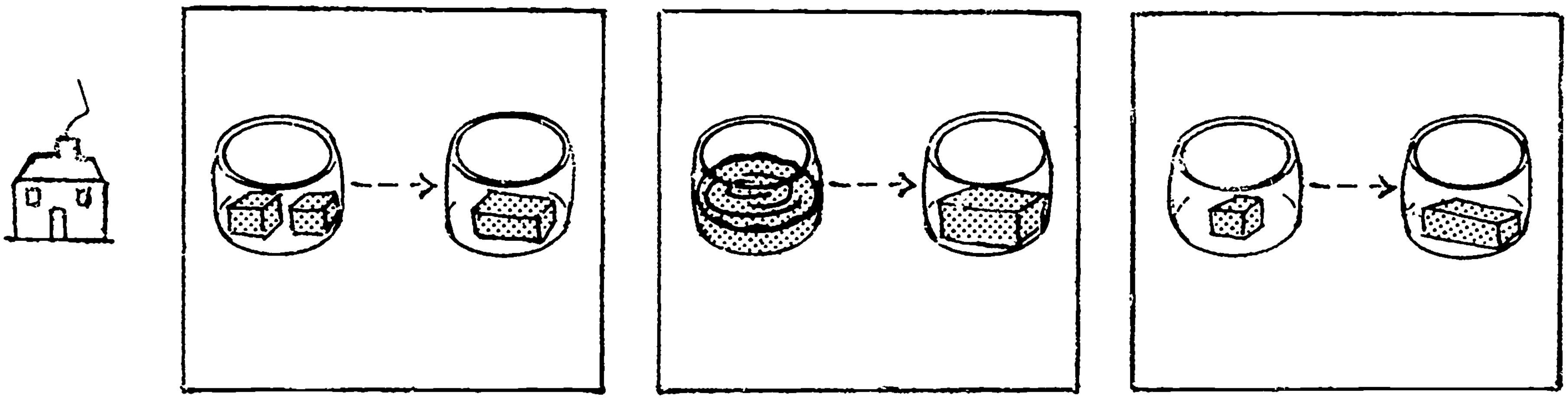
25. Direction: One of these three pictures shows something in a liquid state. Put an X on that picture.



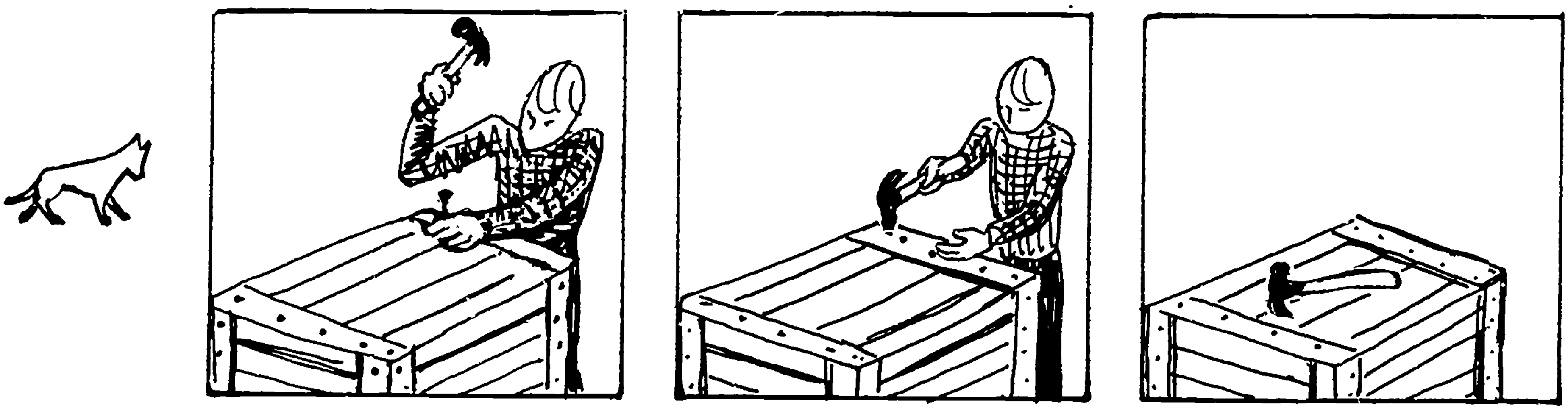
26. Direction: One of these three pictures is about the idea that water can evaporate. Put an X on that picture.



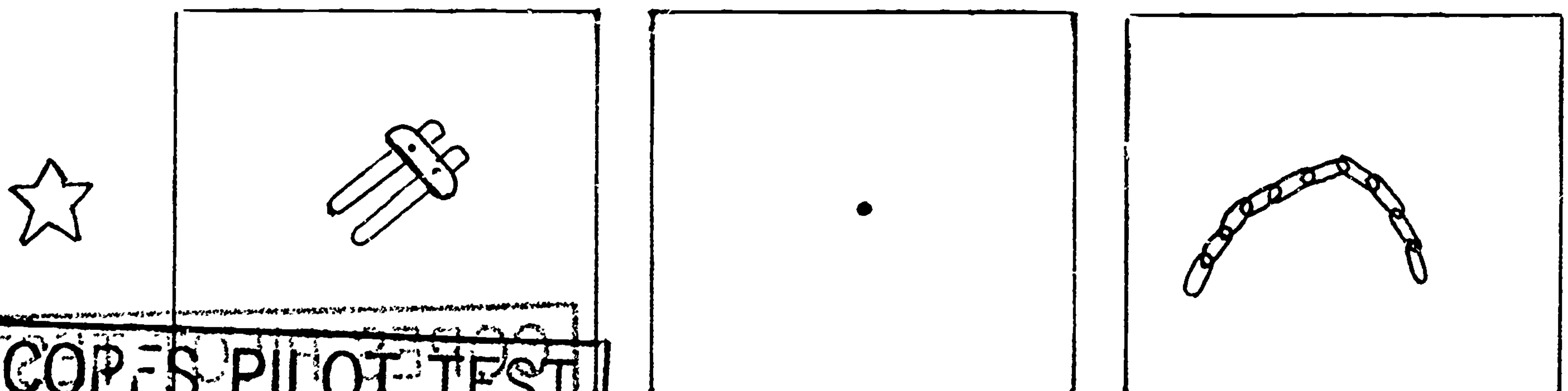
27. Direction: One of these three pictures shows that something can solidify. Put an X on that picture.



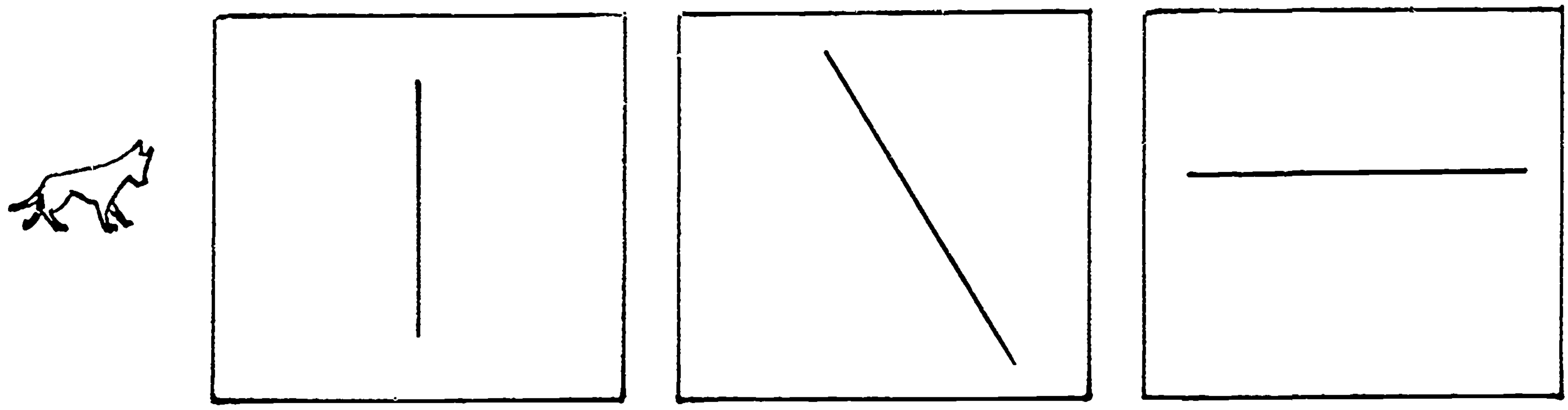
28. Direction: One of these three pictures shows a hammer that has more potential energy than either of the hammers in the other two pictures. Put an X on that picture.



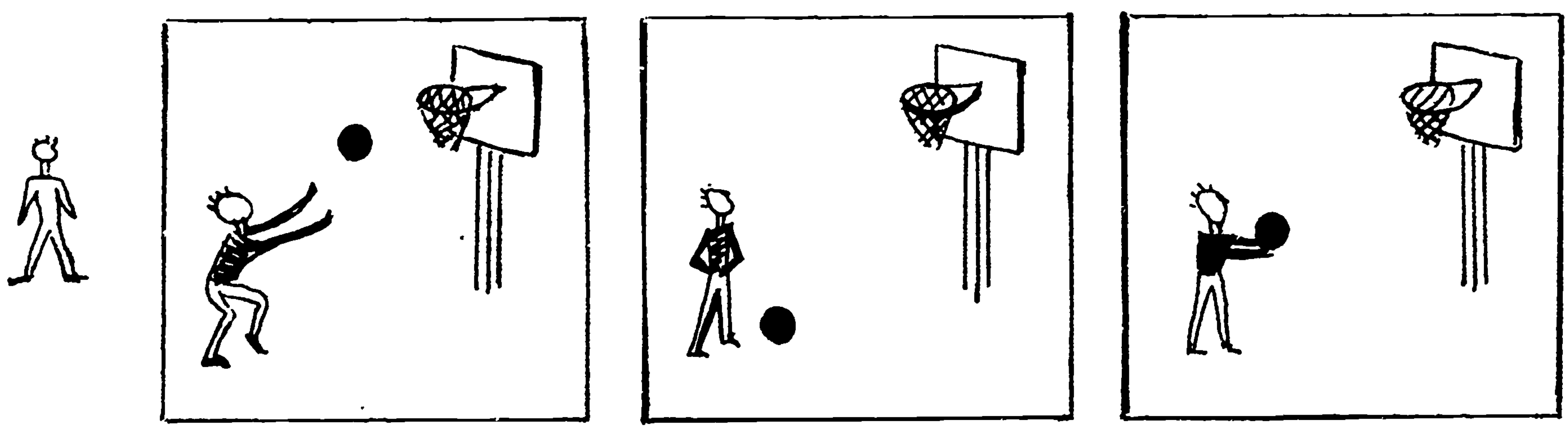
29. Direction: One of these three pictures shows a particle. Put an X on that picture.



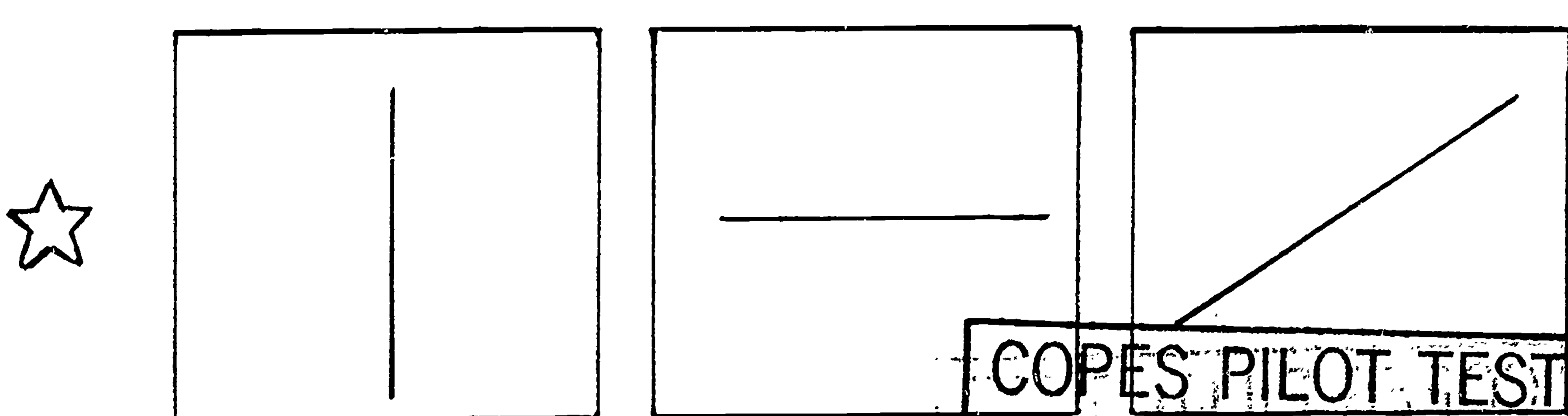
30. Direction: One of these three pictures shows a horizontal line. Put an X on that picture.



31. Direction: One of these three pictures shows a boy who has just done some work. Put an X on that picture.



32. Direction: One of these three pictures shows a vertical line. Put an X on that picture.



PART 2

S A M P L E

We are going to talk about a science word. First, you will hear three meanings for the word. Then you will choose the BEST meaning. The science word is solid. Listen to the meanings. Then put an X in front of the BEST meaning.

_____ (1) A solid is something that is definitely heavy.

_____ (2) A solid is something that has a definite shape.

_____ (3) A solid is something that is definitely hard.

The BEST meaning is (2) because a solid does have a definite shape. Number (1) is wrong because something like water in a pail is heavy but it does not have a definite shape of its own. Number (3) is wrong because something like a rubber band does have a definite shape but it is not hard.

A. The science word is dissolve. Listen to the three meanings. Then put an X in front of the BEST meaning.

_____ (1) Dissolve means to cut something into small pieces and put the pieces in a glass of water or some other liquid.

_____ (2) Dissolve means to stir something in a glass of water or some other liquid.

_____ (3) Dissolve means to make something disappear in a glass of water or some other liquid.

B. The science words are gravitational field. Listen to the three meanings. Then put an X in front of the BEST meaning.

_____ (1) An object's gravitational field is its solid surface.

_____ (2) An object's gravitational field is its magnetic pull on any other object.

_____ (3) An object's gravitational field is the space around that object in which it pulls on any other object.

C. The science word is predict. Listen to the three meanings. Then put an X in front of the BEST meaning.

_____ (1) Predict means to give the right answer.

_____ (2) Predict means to use information you already have to make a guess about what might happen.

_____ (3) Predict means to explain what has happened.

D. The science word is energy. Listen to the three meanings. Then put an X in front of the BEST meaning.

_____ (1) Energy is the ability to choose foods that will make you strong.

_____ (2) Energy is the ability to see something that is very far away.

_____ (3) Energy is the ability to move something from one place to another.

E. The science word is unit. Listen to the three meanings. Then put an X in front of the BEST meaning.

_____ (1) A unit means one whole thing.

_____ (2) A unit means something that is very small.

_____ (3) A unit means a part of something.

F. The science word is temperature. Listen to the three meanings. Then put an X in front of the BEST meaning.

_____ (1) Temperature tells about the weather tomorrow.

_____ (2) Temperature tells about whether a child should stay home from school or not.

_____ (3) Temperature tells about how hot or how cold something is.

G. The science word is graph. Listen to the three meanings. Then put an X in front of the BEST meaning.

_____ (1) To graph means to make a diagram that shows the relation of one thing to another.

_____ (2) To graph means to make a picture of something.

_____ (3) To graph means to make lines on a paper which has been marked off in squares.

H. The science words are a melt. Listen to the three meanings. Then put an X in front of the BEST meaning.

_____ (1) A melt is formed when a substance, such as salt, is dissolved in a warm liquid, such as warm water.

_____ (2) A melt is formed when a solid, such as candle wax, is heated enough to make it a liquid.

_____ (3) A melt is when a warmer, sunny day follows a very cold, snowy day.

I. The science word is weight. Listen to the three meanings. Then put an X in front of the BEST meaning.

_____ (1) The weight of a body on Earth is how big it is.

_____ (2) The weight of a body on Earth is Earth's gravitational pull on it.

_____ (3) The weight of a body on Earth is how fast it will fall to the ground.

J. The science words are a mix. Listen to the three meanings. Then put an X in front of the BEST meaning.

_____ (1) A mix is formed by stirring together substances.

_____ (2) A mix is formed by putting a rock in a glass of water.

_____ (3) A mix is formed by dripping candle wax into a glass of very cold water.

K. The science word is solution. Listen to the three meanings. Then put an X in front of the BEST meaning.

_____ (1) A solution is something that can be poured.

_____ (2) A solution is something with something else dissolved in it.

_____ (3) A solution is something in which a toy boat will float.

L. The science words are a gaseous state. Listen to the three meanings. Then put an X in front of the BEST meaning.

_____ (1) A gaseous state means that a substance is in the form of a gas, not in the form of a solid or a liquid.

_____ (2) A gaseous state means that a substance is evaporating.

_____ (3) A gaseous state means that a substance does not weigh very much.

M. The science word is friction. Listen to the three meanings. Then put an X in front of the BEST meaning.

_____ (1) Friction is a force which pushes two objects apart.

_____ (2) Friction is a force which keeps one surface from moving across another easily.

_____ (3) Friction is a force which makes one object heavier than another.

N. The science words are a heat energy unit. Listen to the three meanings. Then put an X in front of the BEST meaning.

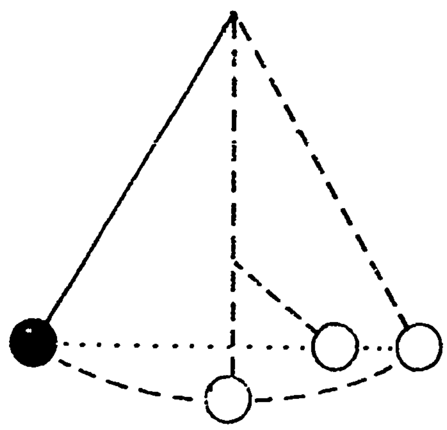
_____ (1) A heat energy unit is the amount of heat energy used in causing one cup of water to boil.

_____ (2) A heat energy unit is a small, standard amount of heat energy.

_____ (3) A heat energy unit is the amount of heat energy given off by a burning candle in one minute.

An experimental test prepared for the pilot study of a Conceptually Oriented Program in Elementary Science, a project supported by a grant from the United States Office of Education and sponsored by New York University.

April 1967

COPES 

Test of

Science Concepts

An Experimental Test
to
Measure Understandings of Concepts
in the
Conservation of Energy Sequence

TEST 1: Section 1

Your Name ______________________

Boy or Girl __________ *Your Grade* __________

Your School ______________________

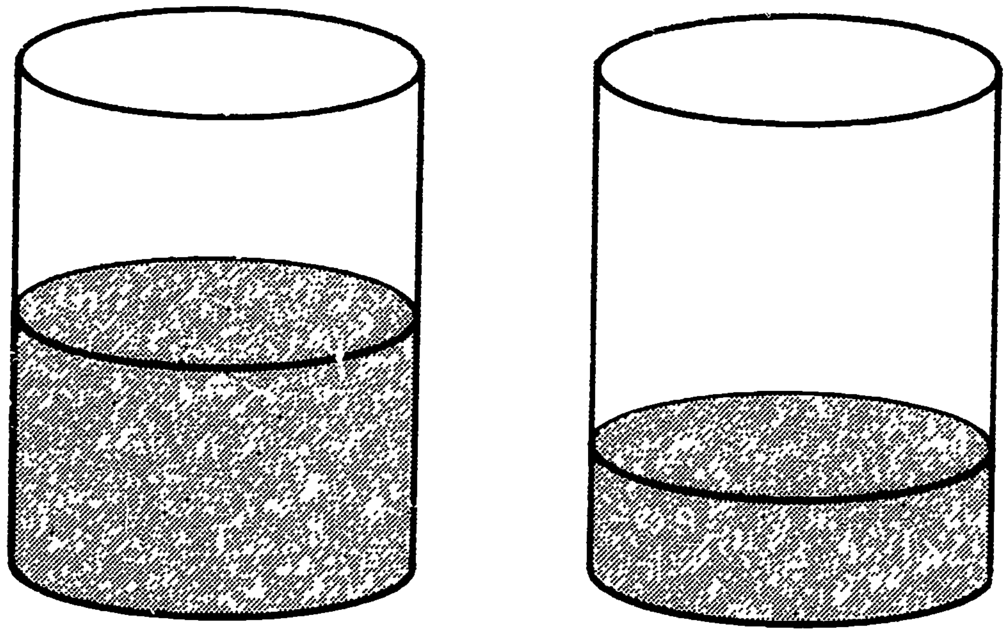
Your Teacher's Name ______________________

Today's Date ______________________

DO NOT OPEN THE TEST BOOKLET UNTIL YOU ARE TOLD TO DO SO.

SAMPLE PROBLEM

MIXING WATER



JAR 1 JAR 2

There are 4 measures of water in jar 1.

There are 2 measures of water in jar 2.

DIRECTIONS: In each part below, put an X in the box in front of the choice that BEST answers the question.

<u>Part A</u>: If you pour all the water from jar 1 into jar 2, how many measures of water will you have when you mix them together in jar 2?

1. 2 measures of water
2. 4 measures of water
3. 6 measures of water
4. 8 measures of water

<u>Part B</u>: If you wanted 5 measures of water in jar 2, what should you do?

1. Pour 1 measure of water from jar 1 into jar 2.
2. Pour 2 measures of water from jar 1 into jar 2.
3. Pour 3 measures of water from jar 1 into jar 2.
4. Pour 4 measures of water from jar 1 into jar 2.

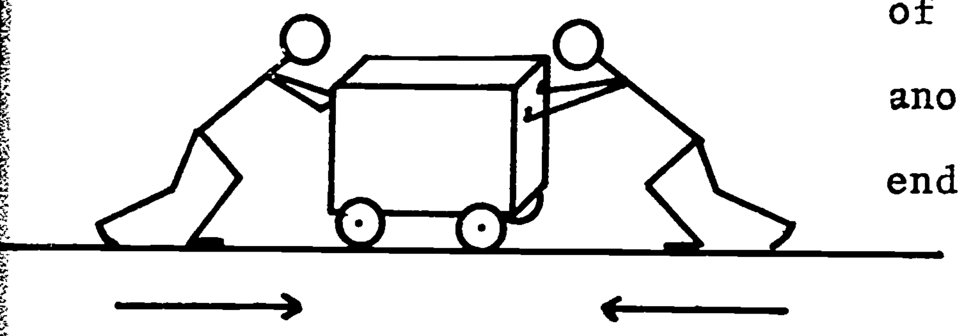
<u>Part C</u>: Which reason would you choose to explain BEST the correct answers to BOTH parts A and B above?

1. When two amounts of a liquid are mixed, the amount of liquid in the mixture is the sum of the amounts of the liquid you started with.
2. When two amounts of a liquid are mixed, the amount of liquid in the mixture is less than the sum of the amounts of the liquid you started with.
3. When two amounts of a liquid are mixed, the amount of liquid in the mixture is more than the sum of the amounts of the liquid you started with.
4. When two amounts of a liquid are mixed, the amount of liquid in the mixture will be in between the amounts of the liquid you started with.

PROBLEM 1

PUSHING BOXES

Box 1

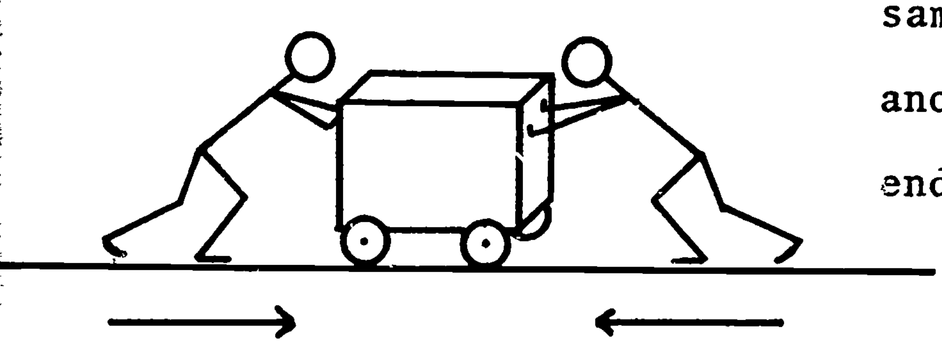


Force of 20 units

Force of 40 units

One boy is pushing on one end of an empty box with 20 units of force; another boy is pushing on its opposite end with 40 units of force.

Box 2

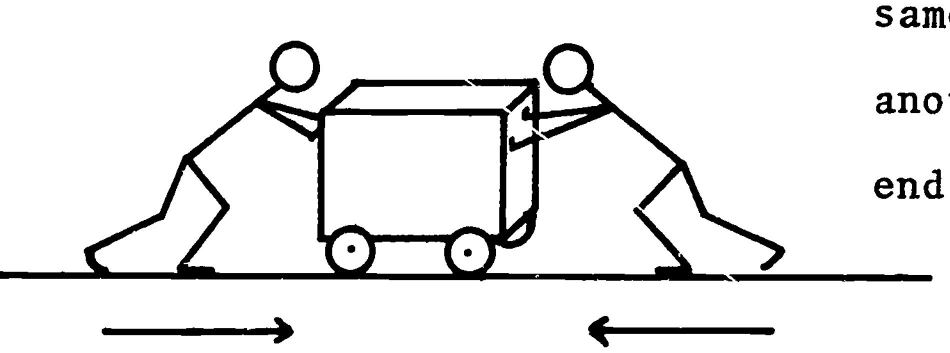


Force of 30 units

Force of 30 units

One boy is pushing on one end of the same kind of box with 30 units of force; another boy is pushing on its opposite end with 30 units of force.

Box 3



Force of 50 units

Force of 30 units

One boy is pushing on one end of the same kind of box with 50 units of force; another boy is pushing on its opposite end with 30 units of force.

DIRECTIONS: In each part below, put an X in the box in front of the choice that BEST answers the question.

Part A: When the forces on the opposite ends of EACH box are applied at the same time, what will happen?

1. ☐ Box 1 will not move from rest.
2. ☐ Box 2 will not move from rest.
3. ☐ Box 3 will not move from rest.
4. ☐ All boxes will move the same distance in the same time.

Part B: If you wanted NONE of the boxes to move when forces are applied on their opposite ends at the same time, what should you do?

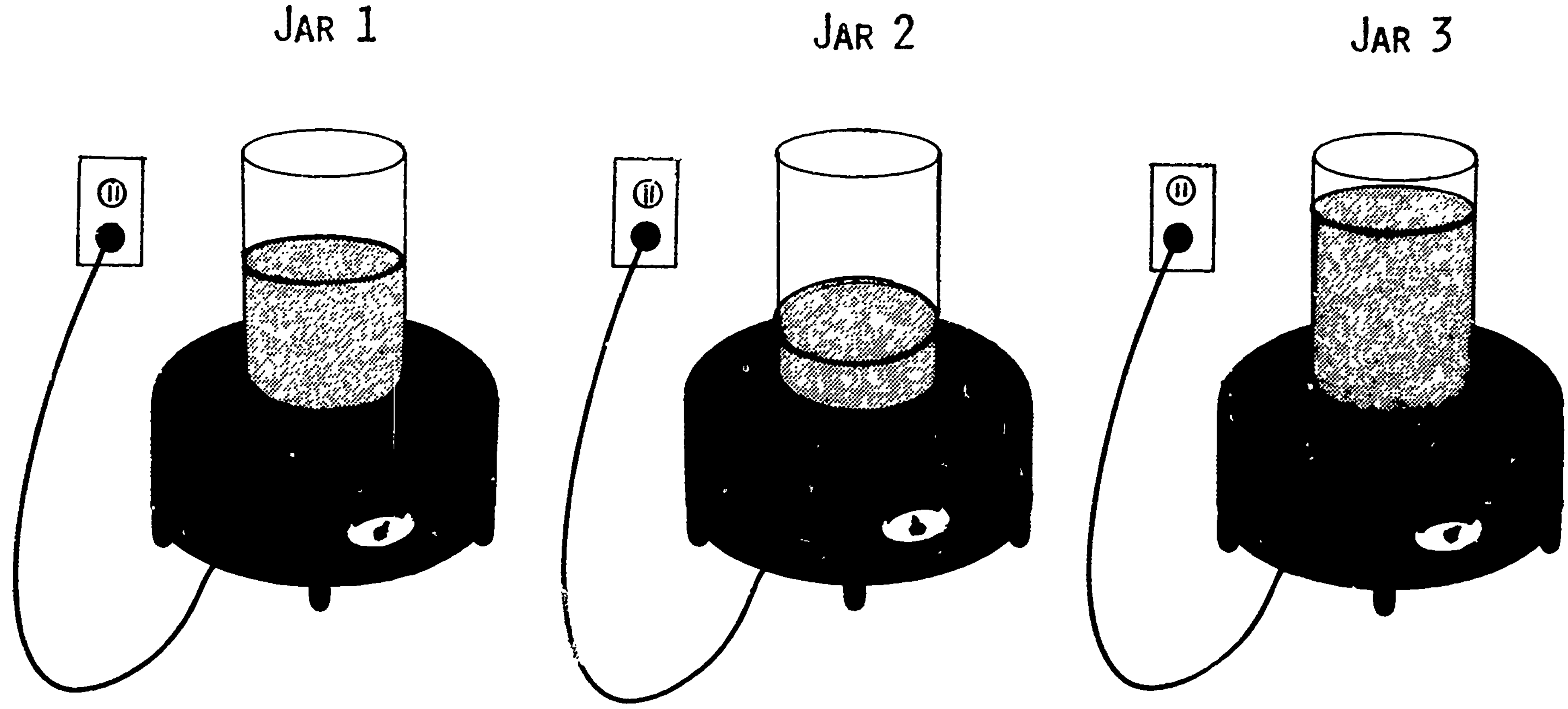
1. ☐ Use a force of about 35 force units on one end and a smaller force on the opposite end of each box.
2. ☐ Use a smaller box.
3. ☐ Use a force of about 25 force units on one end and a larger force on the opposite end of each box.
4. ☐ Use a force of about 30 force units on one end and the same number of force units on the opposite end of each box.

Part C: Which reason would you choose to explain BEST the correct answers to BOTH parts A and B above?

1. ☐ An object moves from rest when the forces pushing on it are balanced.
2. ☐ An object does not move from rest when forces pushing on it are NOT balanced.
3. ☐ An object does not move from rest when the forces pushing on it are balanced.
4. ☐ An object moves from rest when forces do not push or pull on it.

PROBLEM 2

HEATING OIL



There are different amounts of oil at 30°C in jars 1, 2, and 3.

Each jar is heated on a different electric hot plate. Each hot plate is set so that after ten minutes, the temperature in each jar is 50°C.

DIRECTIONS: In each part below, put an X in the box in front of the choice that BEST answers the question.

Part A: What will be true about the addition of heat energy to the three jars?

1. ☐ The greatest amount of heat energy will be added to jar 1.
2. ☐ The greatest amount of heat energy will be added to jar 2.
3. ☐ The greatest amount of heat energy will be added to jar 3.
4. ☐ The same amount of heat energy will be added to each jar.

Part B: If you wanted to have the same amount of heat energy in the oil in jar 1 and in jar 2 after the oil in each jar has been heated to 50°C, what should you do?

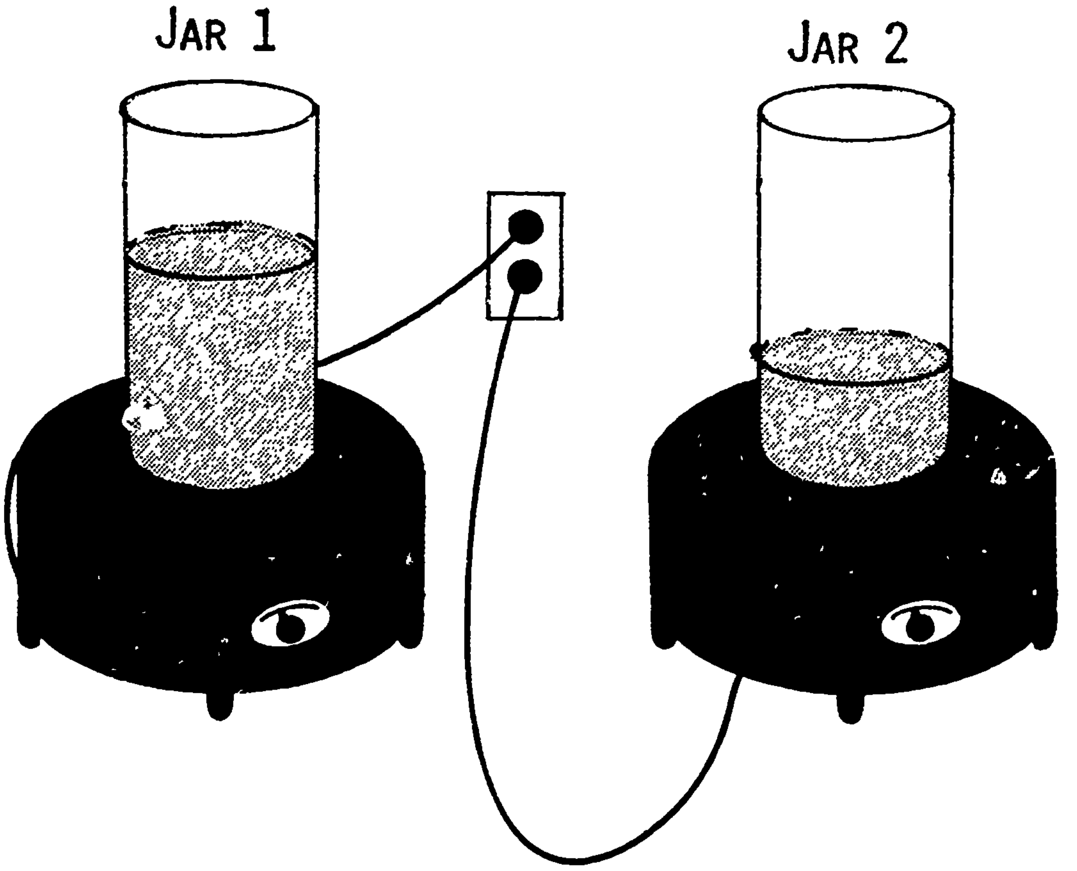
1. ☐ Make the hot plate twice as hot under jar 2.
2. ☐ Start with equal amounts of oil in jar 1 and in jar 2.
3. ☐ Pour some oil from jar 3 into jar 1.
4. ☐ Put a cover on jar 2.

Part C: Which reason would you choose to explain BEST the correct answers to BOTH parts A and B above?

1. ☐ The heat energy of a liquid system depends upon its temperature and the amount of liquid.
2. ☐ The heat energy of equal amounts of a liquid at the same temperature is different.
3. ☐ Two measures of oil at 30°C have the same amount of heat energy as two measures of oil at 50°C.
4. ☐ Four measures of a liquid at 50°C have the same amount of heat energy as two measures of the same liquid at 50°C.

PROBLEM 3

MIXING MILK



In Jar 1, there are four measures of milk at 30°C.

In Jar 2, there are two measures of milk at 50°C.

DIRECTIONS: In each part below, put an X in the box in front of the choice that BEST answers the question.

Part A: When the milk in jar 2 is poured into jar 1 and mixed together, what will be true about the amount of heat energy of the mix?

1. ☐ The amount of heat energy of the mix will be the same as the amount of heat energy of the milk in either jar 1 or jar 2 before mixing.

2. ☐ The amount of heat energy of the mix will be more than the sum of the amounts of heat energy of the milk in jar 1 and in jar 2.

3. ☐ The amount of heat energy of the mix will be the sum of the amounts of heat energy of the milk in jar 1 and in jar 2.

4. ☐ The amount of heat energy of the mix will be less than the amounts of heat energy of the milk in either jar 1 or jar 2 before mixing.

Part B: If you wanted the heat energy of the milk in jar 2 to be double what it is now, what should you do?

1. ☐ Add two more measures of milk at 100°C.

2. ☐ Add two more measures of milk at 20°C.

3. ☐ Add two more measures of milk at 25°C.

4. ☐ Add two more measures of milk at 50°C.

Part C: Which reason would you choose to explain BEST the correct answers to BOTH parts A and B above?

1. ☐ The heat energy of a liquid system is the same as the heat energy of one of its parts.

2. ☐ The heat energy of a liquid system is the sum of the heat energy of all of its parts.

3. ☐ The heat energy of a liquid system depends upon the difference between the heat energy of all of its parts.

4. ☐ The heat energy of a liquid system is the sum of the amounts of the liquid of each of its parts.

PROBLEM 4

THE MELTING ICICLE

On a very cold day in winter, an icicle is brought into a warm room and is put into a container.

DIRECTIONS: In each part below, put an X in the box in front of the choice that BEST answers the question.

Part A: Which statement below BEST describes what will happen as the icicle melts?

1. ☐ Heat will pass from the container to the icicle.
2. ☐ Cold will pass from the container to the icicle.
3. ☐ Cold will pass from the icicle to the container.
4. ☐ Heat will pass from the icicle to the container.

Part B: If you want to change the melted icicle back to ice, what should you do to it?

1. ☐ Add heat.
2. ☐ Take away heat.
3. ☐ Add cold.
4. ☐ Take away cold.

Part C: Which reason would you choose to explain BEST the correct answers to BOTH parts A and B above?

1. ☐ Solids change to liquids and liquids change to gases when cold energy is taken away.
2. ☐ The heat energy that is taken in when a substance changes from a solid to a liquid or from a liquid to a gas is given off when that change of state is reversed.
3. ☐ There is a heat energy exchange when solids change into liquids and when liquids change into gases.
4. ☐ There is more heat energy in a gas than there is in its liquid at the same temperature, and there is more heat energy in a liquid than there is in its solid at the same temperature.

An experimental test prepared for the pilot study of a Conceptually Oriented Program in Elementary Science, a project supported by a grant from the United States Office of Education and sponsored by New York University.

April 1967

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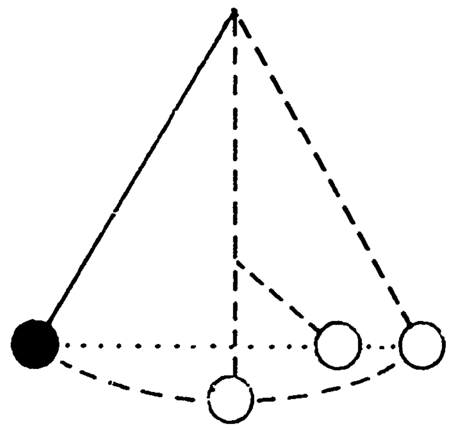


Test of

Science Concepts

An Experimental Test
to
Measure Understandings of Concepts
in the
Conservation of Energy Sequence

TEST 1: Section 2

Your Name ______________________________

Boy or Girl ____________ *Your Grade* ____________

Your School ______________________________

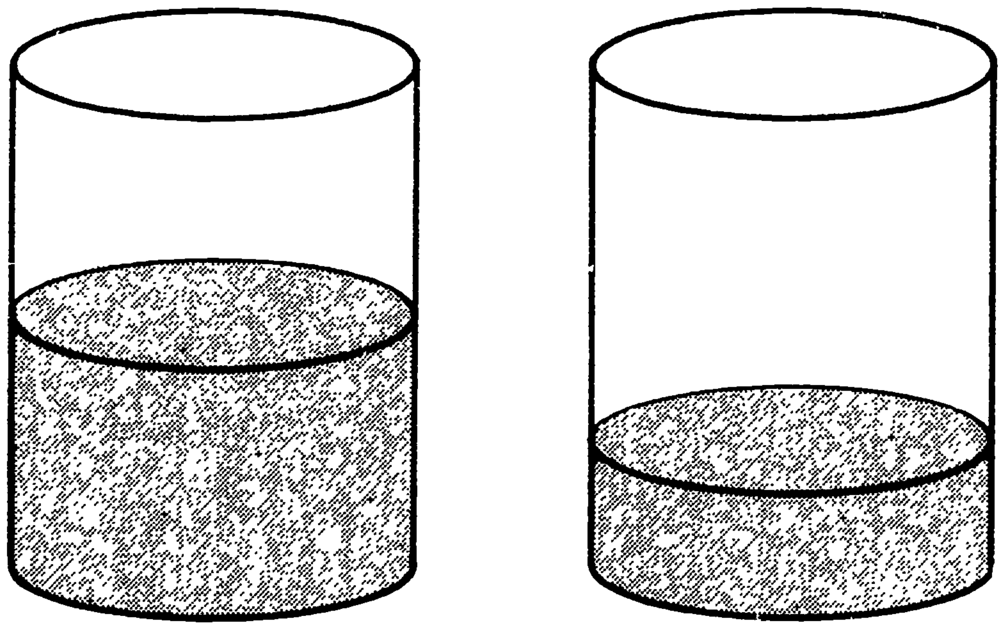
Your Teacher's Name ______________________________

Today's Date ______________________________

DO NOT OPEN THE TEST BOOKLET UNTIL YOU ARE TOLD TO DO SO.

SAMPLE PROBLEM

MIXING WATER



JAR 1 JAR 2

There are 4 measures of water in jar 1.

There are 2 measures of water in jar 2.

DIRECTIONS: In each part below, put an X in the box in front of the choice that BEST answers the question.

Part A: If you pour all the water from jar 1 into jar 2, how many measures of water will you have when you mix them together in jar 2?

1. ☐ 2 measures of water
2. ☐ 4 measures of water
3. ☐ 6 measures of water
4. ☐ 8 measures of water

Part B: If you wanted 5 measures of water in jar 2, what should you do?

1. ☐ Pour 1 measure of water from jar 1 into jar 2.
2. ☐ Pour 2 measures of water from jar 1 into jar 2.
3. ☐ Pour 3 measures of water from jar 1 into jar 2.
4. ☐ Pour 4 measures of water from jar 1 into jar 2.

Part C: Which reason would you choose to explain BEST the correct answers to BOTH parts A and B above?

1. ☐ When two amounts of a liquid are mixed, the amount of liquid in the mixture is the sum of the amounts of the liquid you started with.
2. ☐ When two amounts of a liquid are mixed, the amount of liquid in the mixture is less than the sum of the amounts of the liquid you started with.
3. ☐ When two amounts of a liquid are mixed, the amount of liquid in the mixture is more than the sum of the amounts of the liquid you started with.
4. ☐ When two amounts of a liquid are mixed, the amount of liquid in the mixture will be in between the amounts of the liquid you started with.

PROBLEM 5

CLIMBING A ROPE

John and Betty were practicing rope climbing. John had to pull with 4 force units to lift himself. Betty had to pull with 5 force units to lift herself.

DIRECTIONS: In each part below, put an X in the box in front of the choice that BEST answers the question.

Part A: Betty climbed 8 distance units up the rope. If each child does the same amount of work, how far up the rope will John climb?

1. ☐ 7 distance units
2. ☐ 8 distance units
3. ☐ 9 distance units
4. ☐ 10 distance units

Part B: If you wanted Betty and John to do the same amount of work and to climb the same distance, what would you have to do?

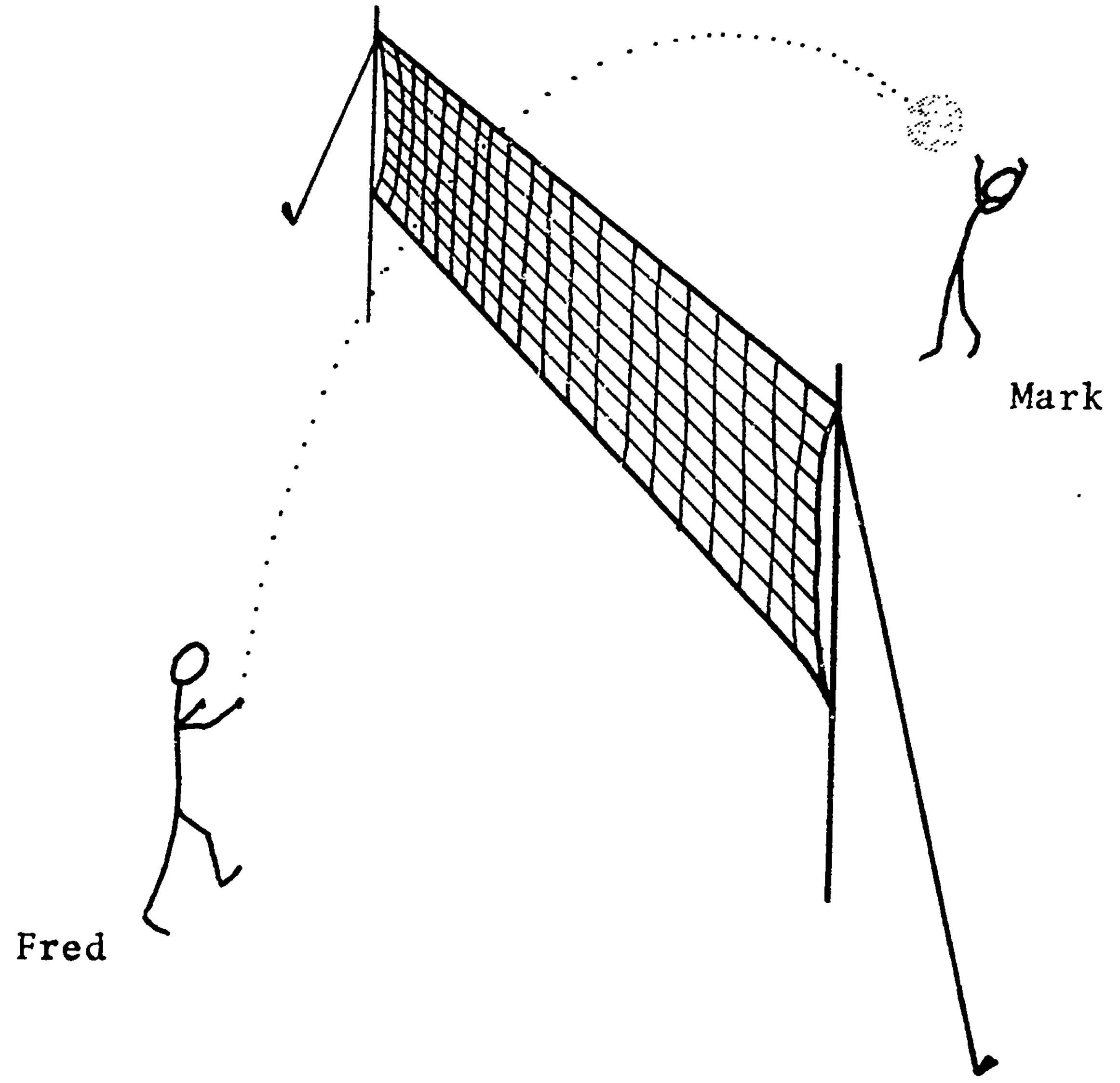
1. ☐ Use a longer rope.
2. ☐ Use a heavier rope.
3. ☐ Wait until John becomes as tall as Betty.
4. ☐ Wait until John becomes as heavy as Betty.

Part C: Which reason would you choose to explain BEST the correct answers to BOTH parts A and B above?

1. ☐ The amount of work done in moving an object depends upon the force used and the distance through which the force moves the object.
2. ☐ The amount of work done in moving an object depends upon how much force is used.
3. ☐ The amount of work done in moving an object depends upon the distance through which the object is moved.
4. ☐ The amount of work done in moving an object through a distance depends upon whether it is being moved by a boy or by a girl.

PROBLEM 6

PRACTICING VOLLEYBALL



Fred and Mark are playing with a volleyball. When Fred hits the ball to Mark, it goes through the air along the path shown by the dotted line in the picture. The ball is highest from the ground when it is directly above the net.

DIRECTIONS: In each part below, put an X in the box in front of the choice that BEST answers the question.

Part A: What will happen to the ball between the time that it is above the net and the time that Mark catches it?

1. ☐ The ball will be losing kinetic energy and gaining potential energy.
2. ☐ The ball will be losing potential energy and gaining kinetic energy.
3. ☐ The ball will be gaining both potential energy and kinetic energy.
4. ☐ The ball will be losing both potential energy and kinetic energy.

Part B: While Fred is practicing with the ball by himself, what should he do if he wants the ball to gain the most potential energy?

1. ☐ Hit the ball straight out as hard as he can.
2. ☐ Hit the ball over the net as hard as he can.
3. ☐ Hit the ball toward the ground as hard as he can.
4. ☐ Hit the ball straight up as hard as he can.

Part C: Which reason would you choose to explain BEST the correct answers to BOTH parts A and B above?

1. ☐ The kinetic energy that an object has can be changed to potential energy, and its potential energy can be changed to kinetic energy.
2. ☐ The amount of potential energy that an object has depends upon how hard it is hit.
3. ☐ The amount of kinetic energy that an object has depends upon how fast the object is moving but not upon the direction in which it is moving.
4. ☐ A moving object sometimes has more kinetic energy than it has potential energy.

PROBLEM 7

MAKING SOLUTIONS

A jar contained water at 32°C. Judy added one measure of a certain salt to the water. She stirred the mixture gently until the salt dissolved. The temperature of the solution was then 25°C.

DIRECTIONS: In each part below, put an X in the box in front of the choice that BEST answers the question.

Part A: When Judy dissolves one more measure of the salt in the solution, what will happen to the temperature of the solution?

1. ☐ The temperature of the solution will drop below 25°C.
2. ☐ The temperature of the solution will rise to 32°C.
3. ☐ The temperature of the solution will be somewhere between 25°C and 32°C.
4. ☐ The temperature of the solution will not change.

Part B: Judy then puts another measure of the salt into the solution. She stirs it very hard, but the salt does not dissolve. What should Judy do to dissolve the extra salt?

1. ☐ She should put a cover on the jar and shake it.
2. ☐ She should put some ice cubes around the jar.
3. ☐ She should warm the solution.
4. ☐ She should pour out part of the solution.

Part C: Which reason would you choose to explain BEST the correct answers to BOTH parts A and B above?

1. ☐ Heat energy is given to water by some solids when they dissolve in the water.
2. ☐ Heat energy is taken away from water by some solids when they dissolve in the water.
3. ☐ Some salts will go into solution when they are stirred in water.
4. ☐ The heat energy of a liquid system depends upon its temperature and the number of measures of liquid.

PROBLEM 8

MAKING CRYSTALS

Dave made a solution of water and a certain salt in a paper cup coated with paraffin wax. When he stirred the solution, crystals suddenly formed.

DIRECTIONS: In each part below, put an X in the box in front of the choice that BEST answers the question.

Part A: What else is most likely to happen when the crystals form?

1. [ ] Ice crystals may form in the solution.
2. [ ] Water droplets may form on the outside of the cup.
3. [ ] The paraffin wax on the cup may begin to melt.
4. [ ] A small cloud may form in the air over the cup.

Part B: What should Dave do to make the crystals form more quickly when he stirs the solution?

1. [ ] He should put the cup in a bucket of ice.
2. [ ] He should put the cup in a bucket of warm water.
3. [ ] He should add some water to the solution.
4. [ ] He should pour out some of the solution.

Part C: Which reason would you choose to explain BEST the correct answers to BOTH parts A and B above?

1. [ ] Heat energy is taken in by some solids when they dissolve in water.
2. [ ] There is heat energy in a solution of water and salt.
3. [ ] A greater amount of a solid salt can be dissolved in a liquid when heat energy is added to the liquid for a long time.
4. [ ] The heat energy that is taken in by a solid when it dissolves in water is given out when that solid is formed again.

An experimental test prepared for the pilot study of a Conceptually Oriented Program in Elementary Science, a project supported by a grant from the United States Office of Education and sponsored by New York University.

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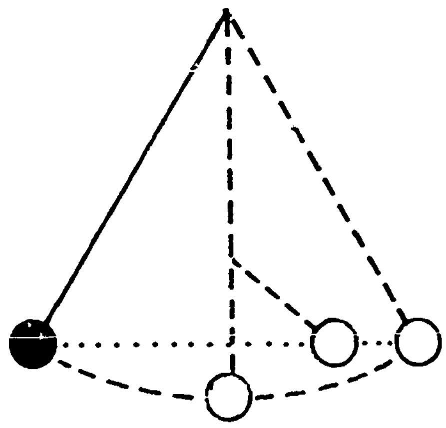
COPES



Test of Science Concepts

An Experimental Test
to
Measure Understandings of Concepts
in the
Conservation of Energy Sequence

TEST 1: Section 3

Your Name ______________________________

Boy or Girl ______________ *Your Grade* ______________

Your School ______________________________

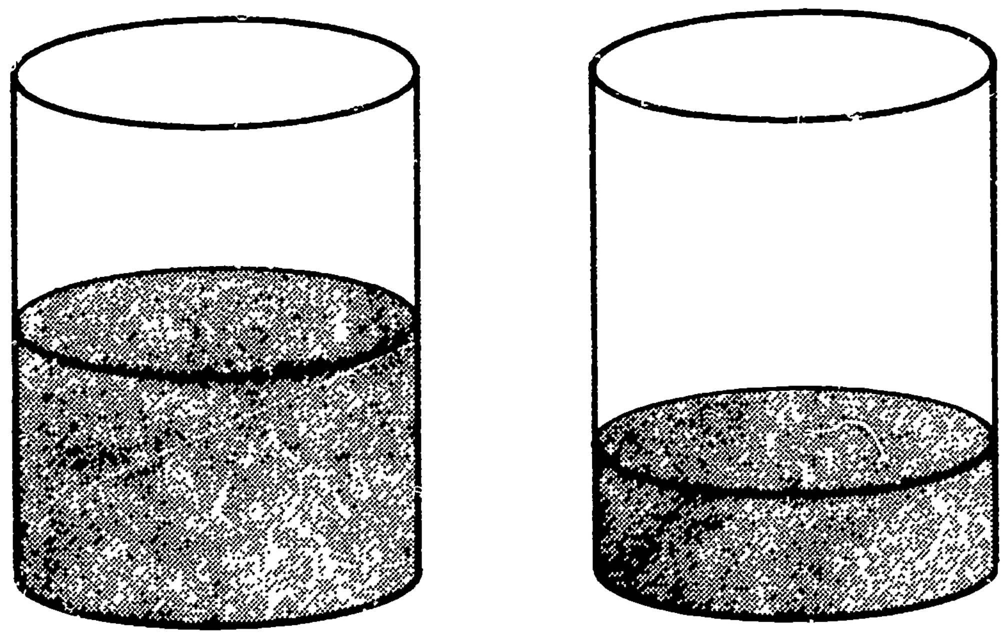
Your Teacher's Name ______________________________

Today's Date ______________________________

DO NOT OPEN THE TEST BOOKLET UNTIL YOU ARE TOLD TO DO SO.

SAMPLE PROBLEM

MIXING WATER



JAR 1 JAR 2

There are 4 measures of water in jar 1.

There are 2 measures of water in jar 2.

DIRECTIONS: In each part below, put an X in the box in front of the choice that BEST answers the question.

Part A: If you pour all the water from jar 1 into jar 2, how many measures of water will you have when you mix them together in jar 2?

1. ☐ 2 measures of water
2. ☐ 4 measures of water
3. ☐ 6 measures of water
4. ☐ 8 measures of water

Part B: If you wanted 5 measures of water in jar 2, what should you do?

1. ☐ Pour 1 measure of water from jar 1 into jar 2.
2. ☐ Pour 2 measures of water from jar 1 into jar 2.
3. ☐ Pour 3 measures of water from jar 1 into jar 2.
4. ☐ Pour 4 measures of water from jar 1 into jar 2.

Part C: Which reason would you choose to explain BEST the correct answers to BOTH parts A and B above?

1. ☐ When two amounts of a liquid are mixed, the amount of liquid in the mixture is the sum of the amounts of the liquid you started with.
2. ☐ When two amounts of a liquid are mixed, the amount of liquid in the mixture is less than the sum of the amounts of the liquid you started with.
3. ☐ When two amounts of a liquid are mixed, the amount of liquid in the mixture is more than the sum of the amounts of the liquid you started with.
4. ☐ When two amounts of a liquid are mixed, the amount of liquid in the mixture will be in between the amounts of the liquid you started with.

PROBLEM 9

THE CHANGING ROCK

Susan put a large salt crystal from her rock collection on a windowsill in the hot sun where it gained a great deal of heat energy. Later, when she returned to her room, Susan picked up the crystal and saw that its color had changed. She put it on a table in a cool, shady part of the room. Then she went to the kitchen to get a moist sponge to wipe off the crystal.

DIRECTIONS: In each part below, put an X in the box in front of the choice that BEST answers the question.

Part A: As Susan wipes off the salt crystal with the moist sponge, it changes back to its original color and feels dry. What else would you expect to be happening to the crystal as she wipes it?

1. ☐ The crystal will gain heat energy.
2. ☐ The crystal will give off heat energy.
3. ☐ The crystal will gain heat energy and then give it off.
4. ☐ The crystal will neither gain heat energy nor give it off

Part B: If Susan wants to keep another crystal of the same kind of salt from changing in appearance when she places it on the windowsill, what should she do?

1. ☐ She should put the crystal where it will get more light.
2. ☐ She should keep the crystal from gaining heat energy.
3. ☐ She should add heat energy to the crystal.
4. ☐ She should put a dark cloth over the crystal.

Part C: Which reason would you choose to explain BEST the correct answers to BOTH parts A and B above?

1. ☐ Heat energy is given off by some dry solids when they are being dissolved in water.
2. ☐ The heat energy that is gained by a dry solid in the sun is given off when that solid is in the shade.
3. ☐ A greater amount of a salt that feels dry can be dissolved in a liquid when heat energy and light energy are added to the salt for a long time.
4. ☐ The heat energy needed to drive off water particles that are joined to a salt that feels dry is given out when water particles are joined to the salt again.

PROBLEM 10

SLIDING

Bob climbed to the top of a slide at the playground. While he was sitting at the top of the slide, he had 30 units of potential energy. He started sliding and noticed that the seat of his pants became warmer as his kinetic energy increased.

DIRECTIONS: In each part below, put an X in the box in front of the choice that BEST answers the question.

Part A: What do you predict about Bob's kinetic energy just before he goes off the end of the slide?

1. ☐ None of his kinetic energy will come from the 30 units of potential energy he had at the top of the slide.

2. ☐ His kinetic energy and the heat energy produced by sliding will equal the 30 units of potential energy he had at the top of the slide.

3. ☐ His kinetic energy and the heat energy produced by sliding will be more than the 30 units of potential energy he had at the top of the slide.

4. ☐ His kinetic energy will be more than the 30 units of potential energy he had at the top of the slide.

Part B: If Bob wants to go down a slide and have more than 30 units of kinetic energy when he reaches the ground, what should he do?

1. ☐ Rub wax on the slide so that he can slide down faster and the seat of his pants will not get so warm.

2. ☐ Use the slide on a cold day so that the slide and the seat of his pants will not get so warm.

3. ☐ Choose another slide that is higher but not as long.

4. ☐ Choose another slide that is longer but not as high.

Part C: Which reason would you choose to explain BEST the correct answers to BOTH parts A and B above?

1. ☐ The kinetic energy that an object has can be changed into potential energy.

2. ☐ An object moves from rest when the forces pushing on it are unbalanced.

3. ☐ The sum of all forms of energy produced when the potential energy of an object is decreasing is equal to the potential energy that the object has lost.

4. ☐ Heat energy is produced when an unbalanced force moves an object through a distance over a surface where friction is present between the object and the surface.

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